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(54) **AUTONOMOUS VESSEL FOR UNMANNED COMBAT AERIAL VEHICLE (UCAV) CARRIER OPERATIONS**

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(51) **Int. Cl.**
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F41F 3/07 (2006.01)
F42B 19/10 (2006.01)
B64C 39/02 (2006.01)

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CPC ***B63G 8/001*** (2013.01); ***B64C 39/024*** (2013.01); *B32B 2605/16* (2013.01); *B63G 2008/004* (2013.01); *B64C 2201/126* (2013.01); *B64C 2201/205* (2013.01)

(58) **Field of Classification Search**
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USPC 114/20.1, 316, 317, 318, 319; 244/63
See application file for complete search history.

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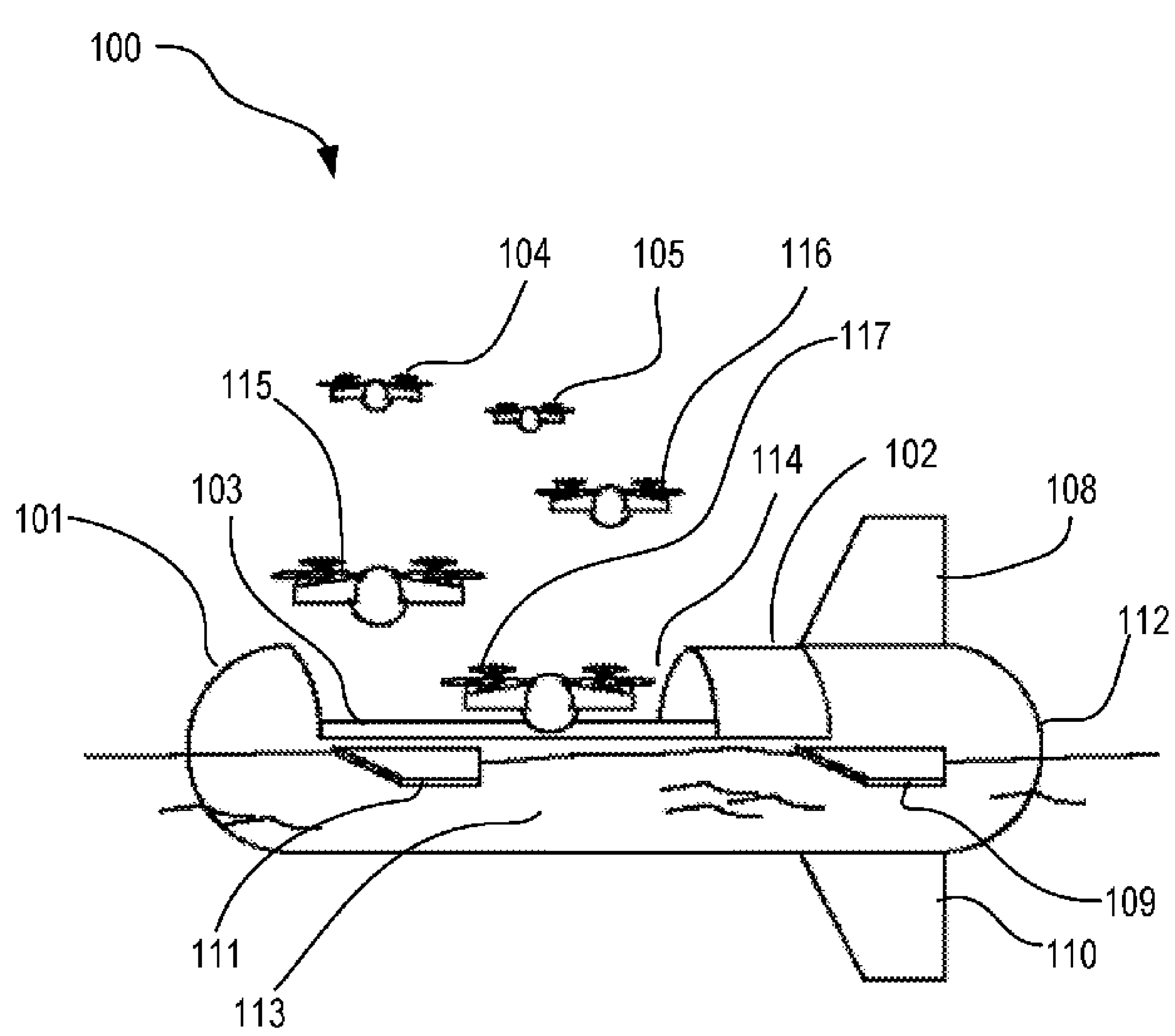
(57) **ABSTRACT**

An autonomous vessel comprises a hull. The hull contains a plurality of subsystems. The subsystems comprise a sensor subsystem configured to sense potential target information regarding a potential target, a database subsystem configured to store target characterization information, a processing subsystem coupled to the sensing subsystem and to the database subsystem, and an ordnance subsystem. The processing subsystem is configured to process the potential target information according to the target characterization information to confirm the potential target as being a confirmed target. The ordnance subsystem comprises an ordnance magazine configured to store ordnance, the ordnance deliverable by an unmanned combat aerial vehicle (UCAV). The ordnance is deployable against the confirmed target.

20 Claims, 15 Drawing Sheets



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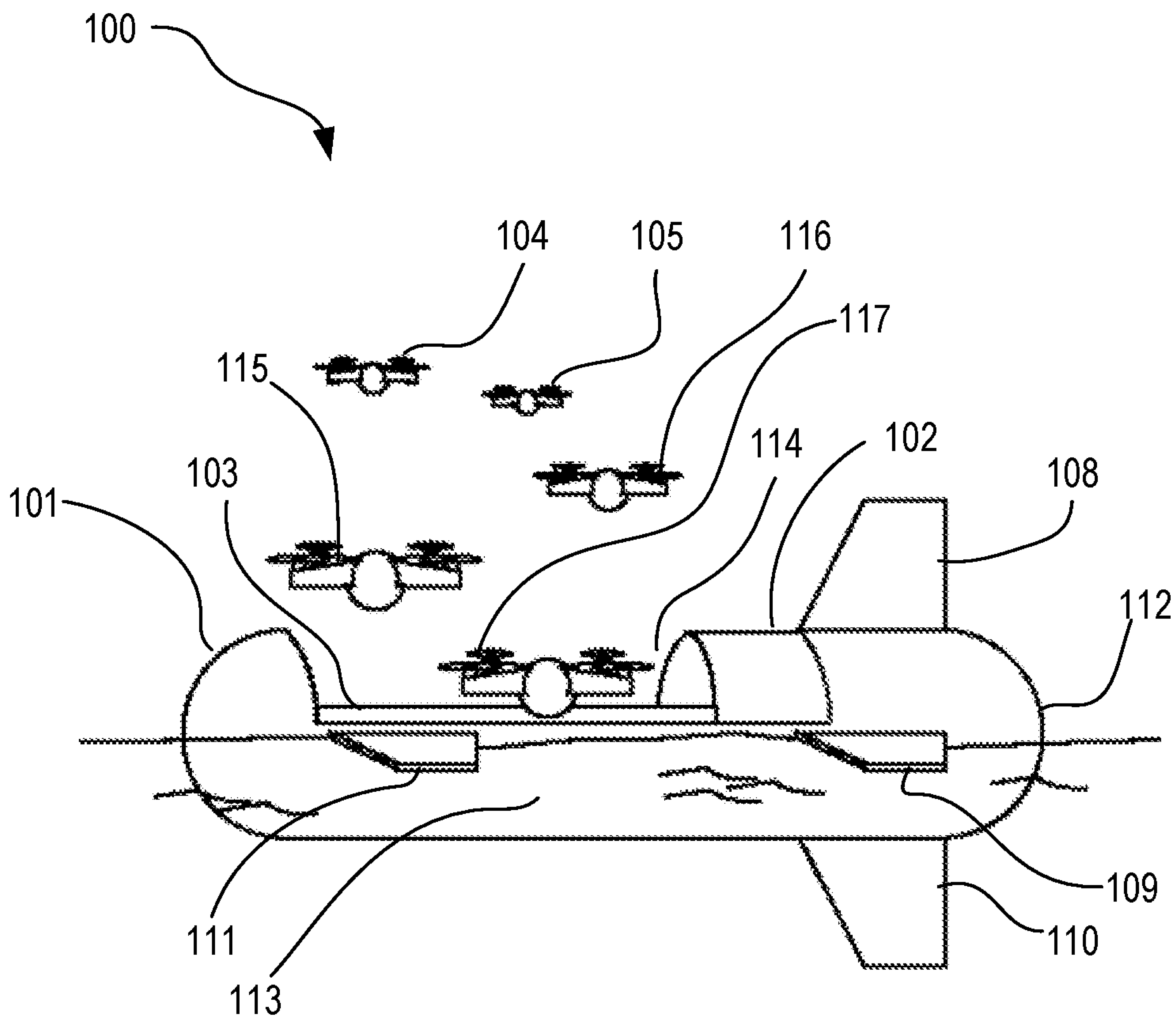

FIG. 1

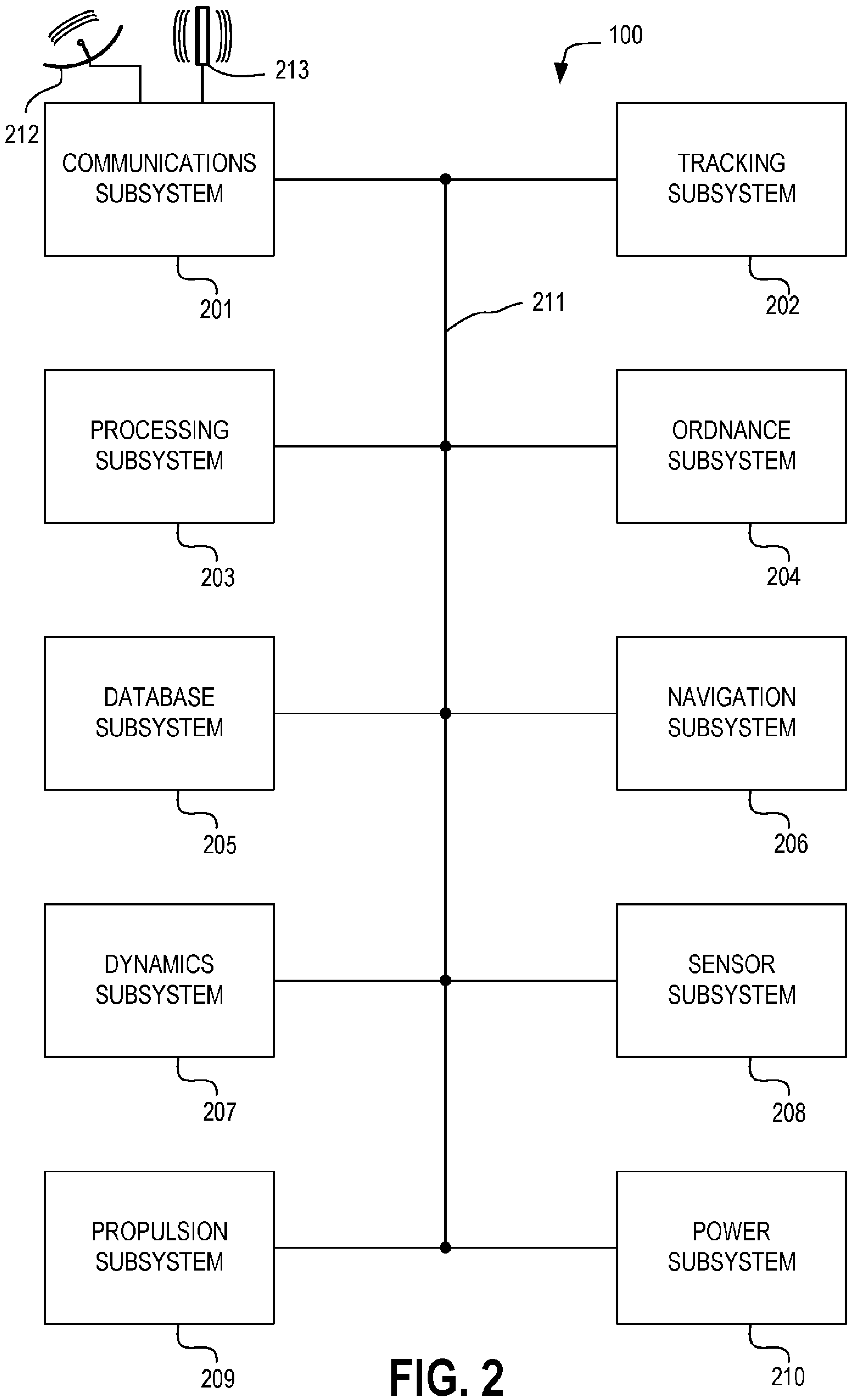
100
212
213
COMMUNICATIONS SUBSYSTEM
201
TRACKING SUBSYSTEM
202
211
PROCESSING SUBSYSTEM
203
ORDNANCE SUBSYSTEM
204
DATABASE SUBSYSTEM
205
NAVIGATION SUBSYSTEM
206
DYNAMICS SUBSYSTEM
207
SENSOR SUBSYSTEM
208
PROPULSION SUBSYSTEM
209
POWER SUBSYSTEM
210

FIG. 2

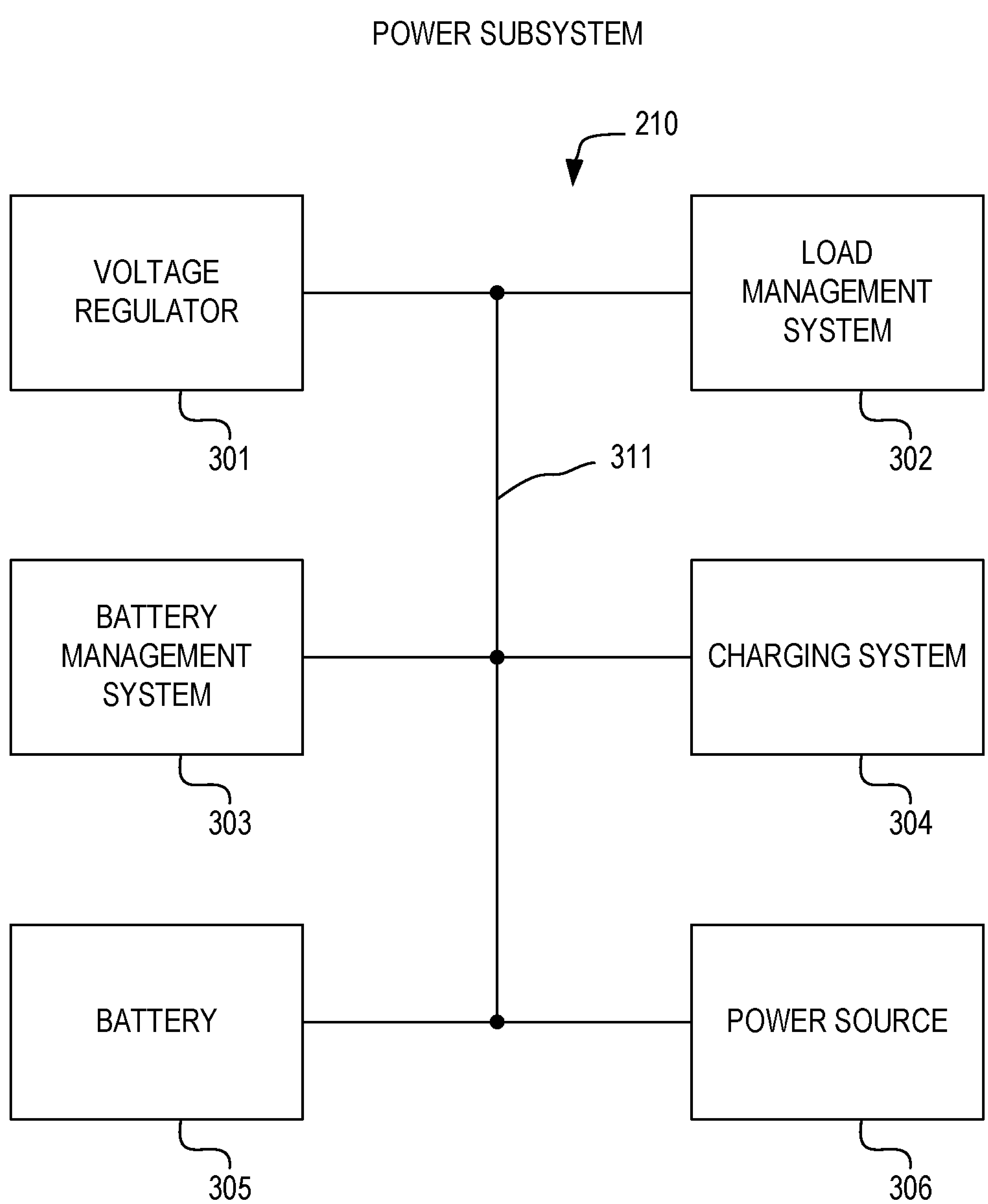
POWER SUBSYSTEM
210
VOLTAGE REGULATOR
301
LOAD MANAGEMENT SYSTEM
302
311
BATTERY MANAGEMENT SYSTEM
303
CHARGING SYSTEM
304
BATTERY
305
POWER SOURCE
306

FIG. 3

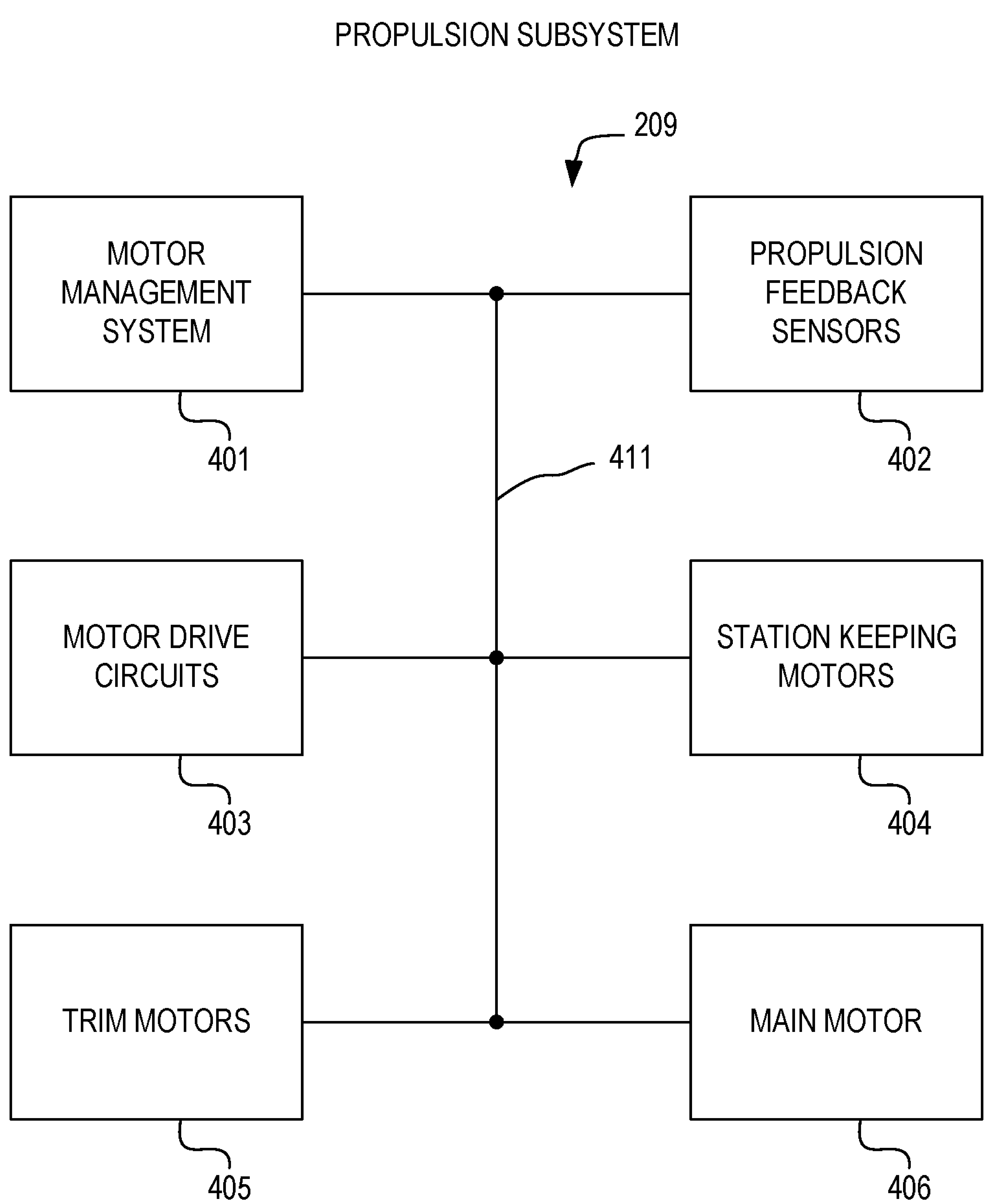
PROPULSION SUBSYSTEM
209
MOTOR MANAGEMENT SYSTEM
401
PROPULSION FEEDBACK SENSORS
402
411
MOTOR DRIVE CIRCUITS
403
STATION KEEPING MOTORS
404
TRIM MOTORS
405
MAIN MOTOR
406

FIG. 4

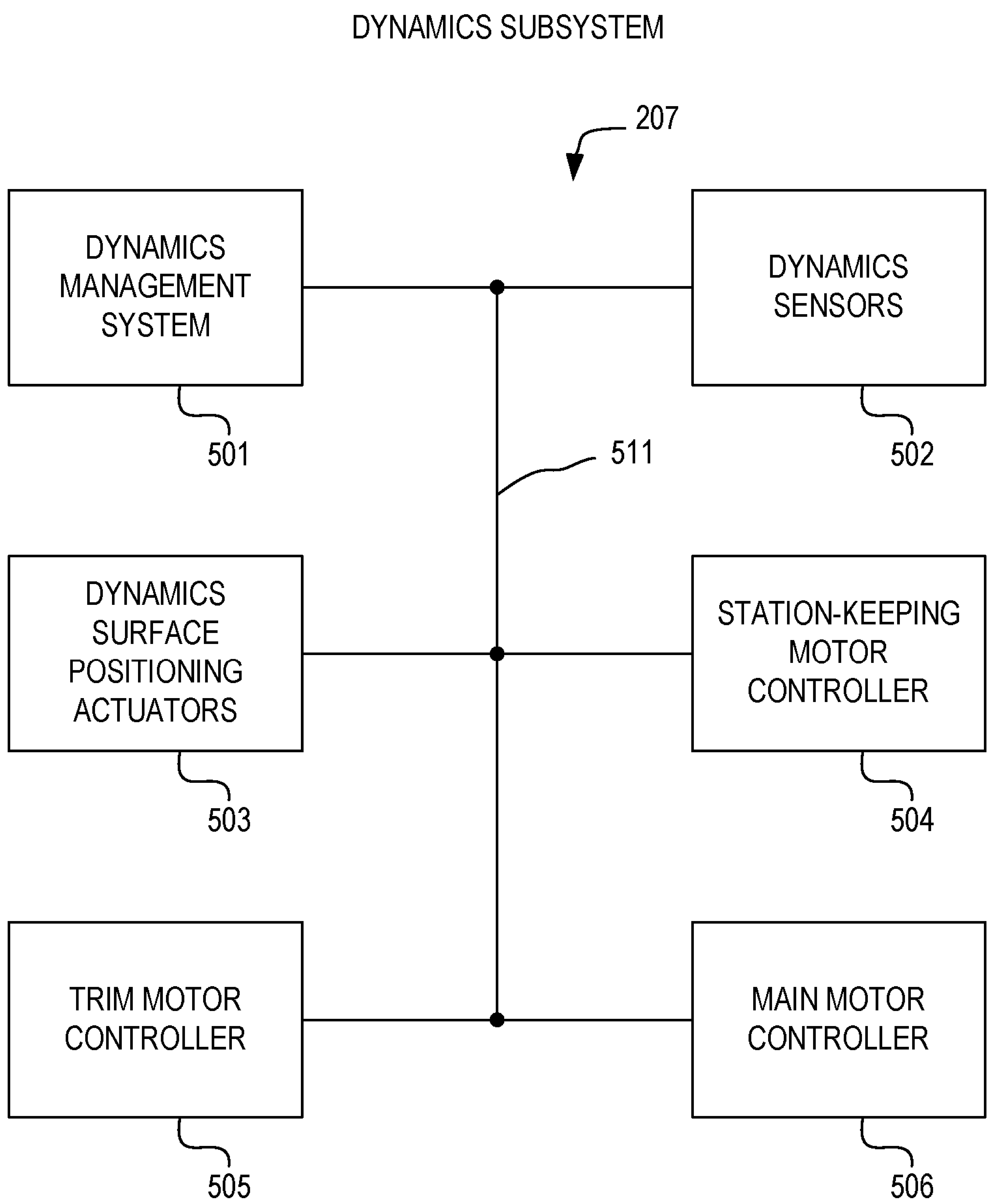
DYNAMICS SUBSYSTEM
207
DYNAMICS MANAGEMENT SYSTEM
501
DYNAMICS SENSORS
502
511
DYNAMICS SURFACE POSITIONING ACTUATORS
503
STATION-KEEPING MOTOR CONTROLLER
504
TRIM MOTOR CONTROLLER
505
MAIN MOTOR CONTROLLER
506

FIG. 5

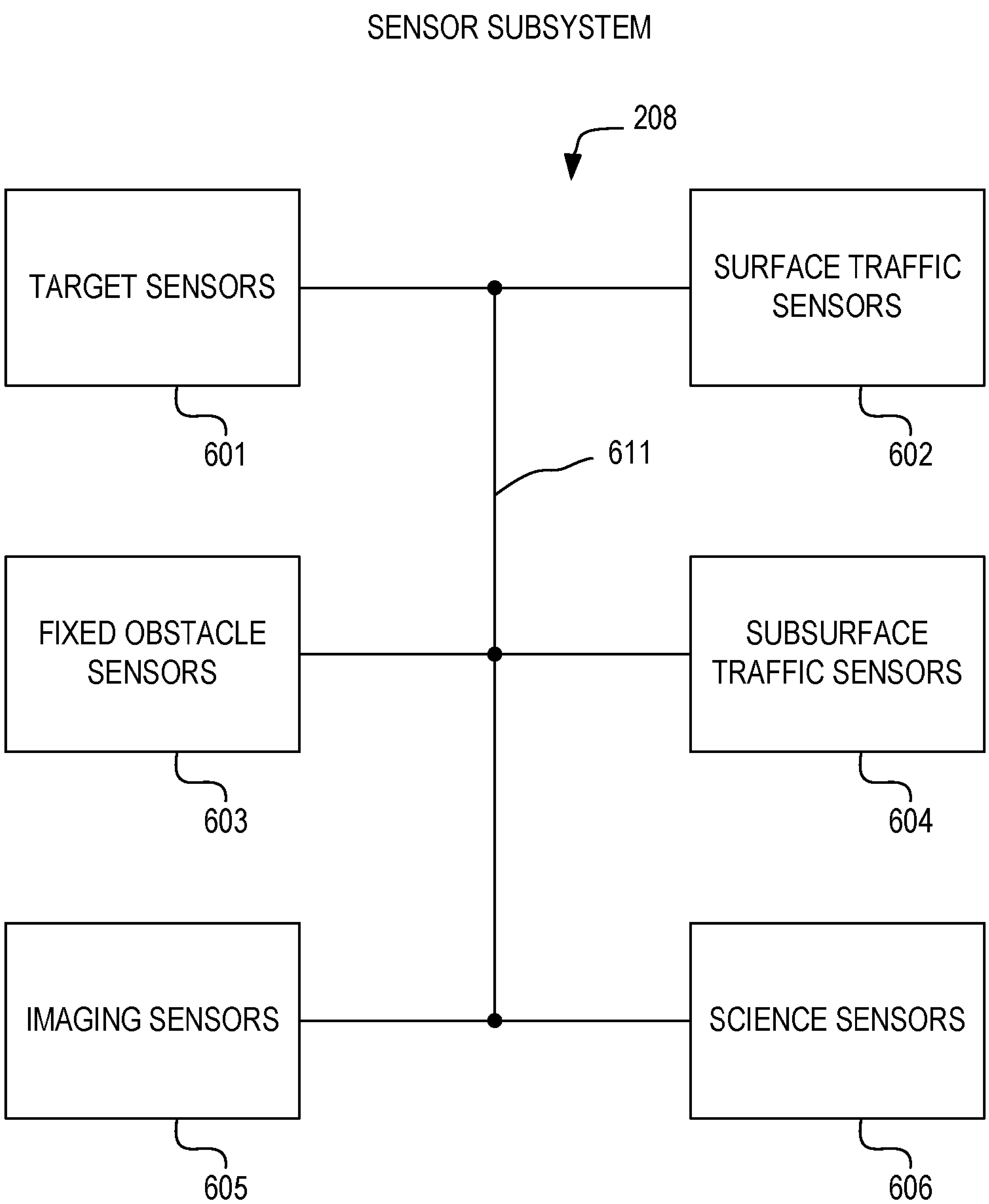
SENSOR SUBSYSTEM
208
TARGET SENSORS
601
SURFACE TRAFFIC SENSORS
602
611
FIXED OBSTACLE SENSORS
603
SUBSURFACE TRAFFIC SENSORS
604
IMAGING SENSORS
605
SCIENCE SENSORS
606

FIG. 6

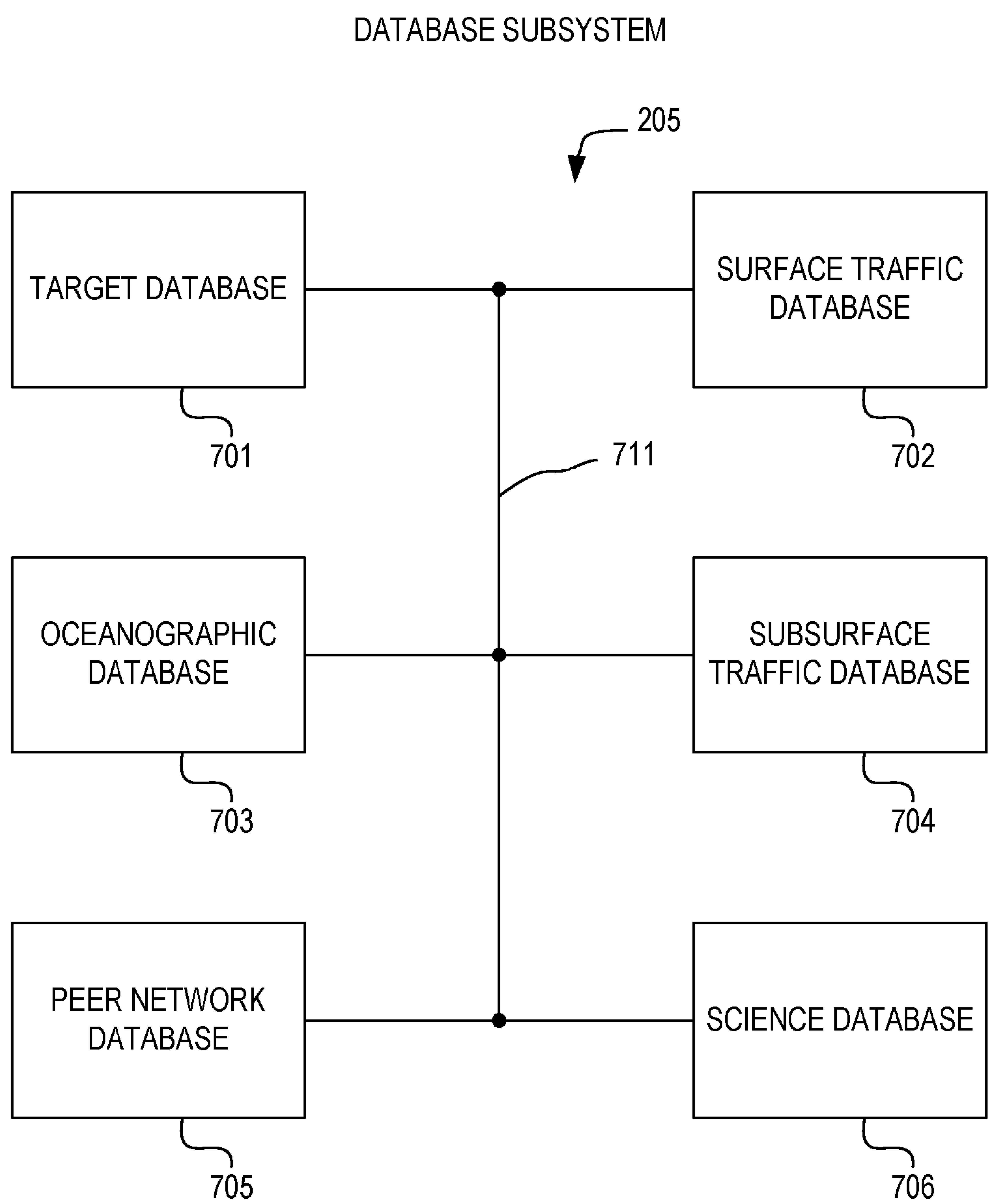
DATABASE SUBSYSTEM
205
TARGET DATABASE
701
SURFACE TRAFFIC DATABASE
702
711
OCEANOGRAPHIC DATABASE
703
SUBSURFACE TRAFFIC DATABASE
704
PEER NETWORK DATABASE
705
SCIENCE DATABASE
706

FIG. 7

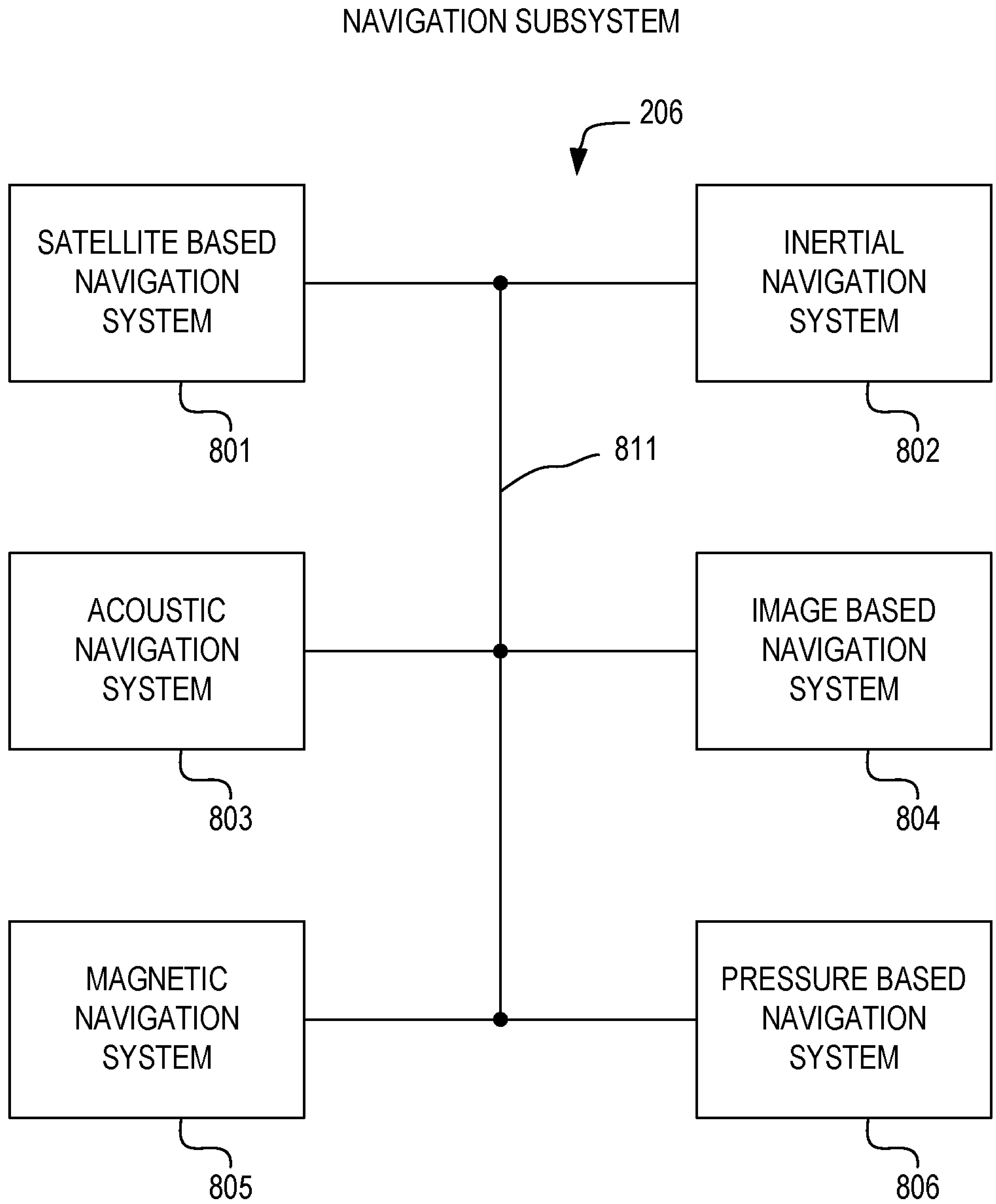
NAVIGATION SUBSYSTEM
206
SATELLITE BASED NAVIGATION SYSTEM
801
INERTIAL NAVIGATION SYSTEM
802
811
ACOUSTIC NAVIGATION SYSTEM
803
IMAGE BASED NAVIGATION SYSTEM
804
MAGNETIC NAVIGATION SYSTEM
805
PRESSURE BASED NAVIGATION SYSTEM
806

FIG. 8

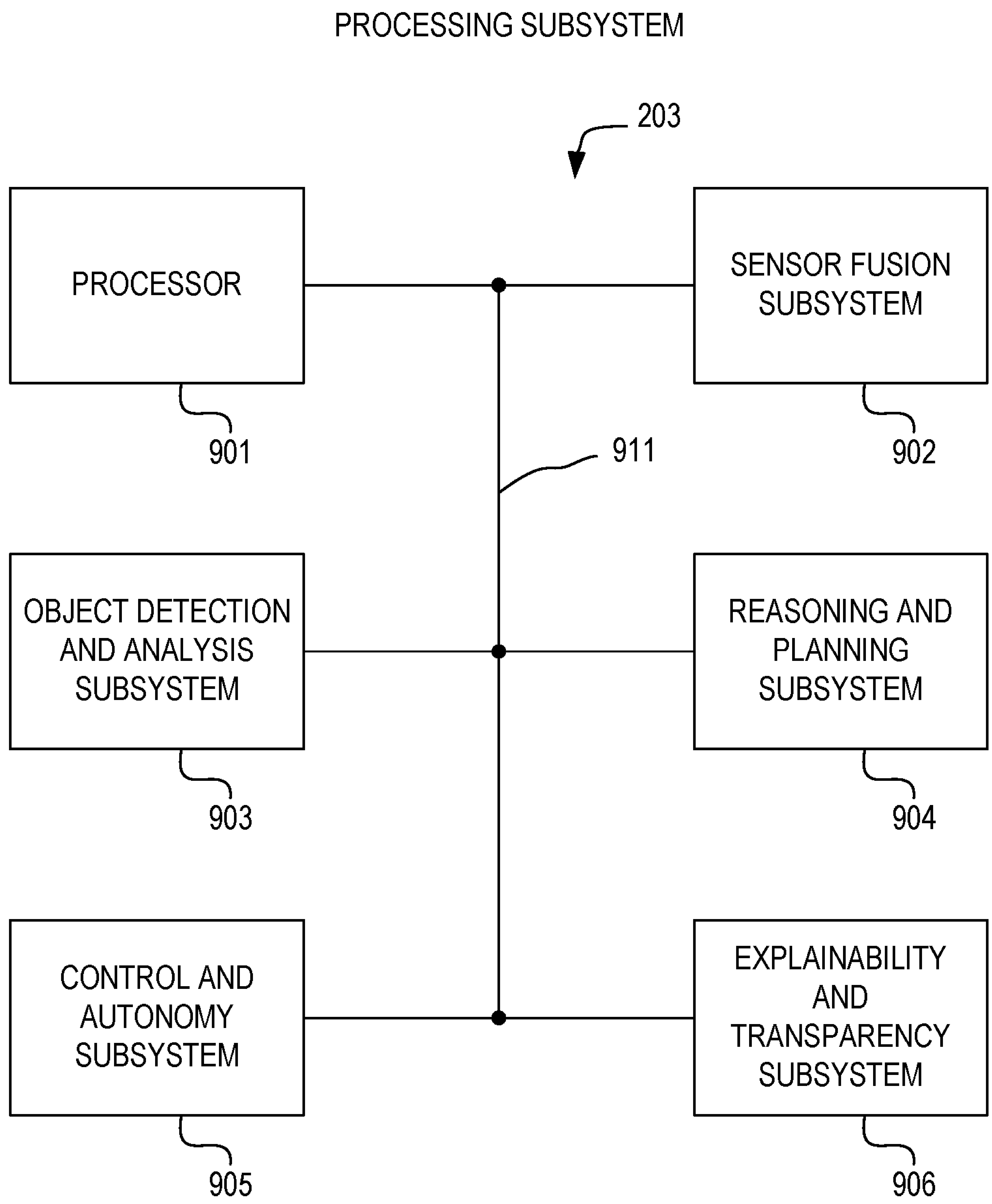
PROCESSING SUBSYSTEM
203
PROCESSOR
901
SENSOR FUSION SUBSYSTEM
902
911
OBJECT DETECTION AND ANALYSIS SUBSYSTEM
903
REASONING AND PLANNING SUBSYSTEM
904
CONTROL AND AUTONOMY SUBSYSTEM
905
EXPLAINABILITY AND TRANSPARENCY SUBSYSTEM
906

FIG. 9

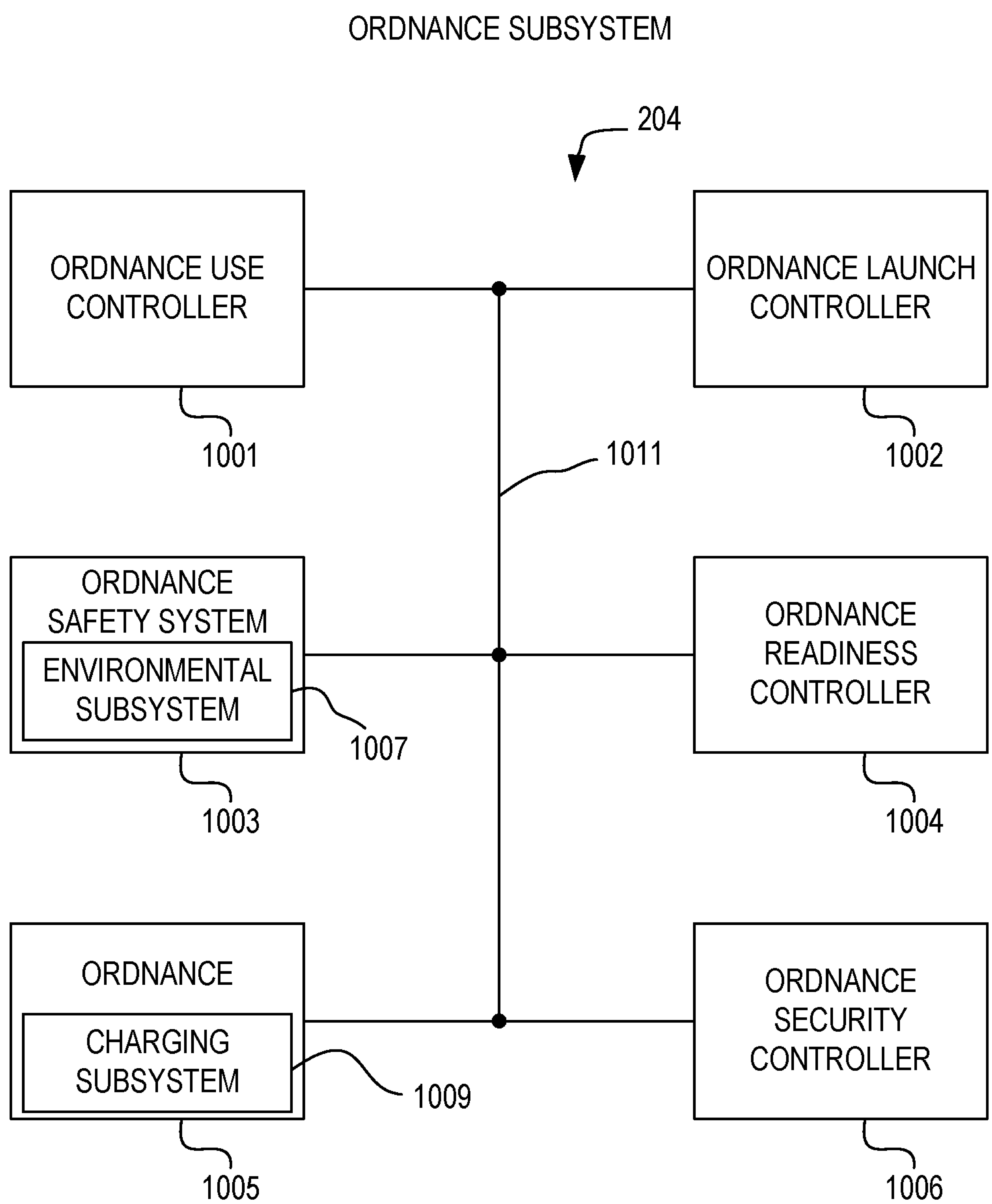
ORDNANCE SUBSYSTEM
204
ORDNANCE USE CONTROLLER
1001
ORDNANCE LAUNCH CONTROLLER
1002
1011
ORDNANCE SAFETY SYSTEM
ENVIRONMENTAL SUBSYSTEM
1007
1003
ORDNANCE READINESS CONTROLLER
1004
ORDNANCE
CHARGING SUBSYSTEM
1009
1005
ORDNANCE SECURITY CONTROLLER
1006

FIG. 10

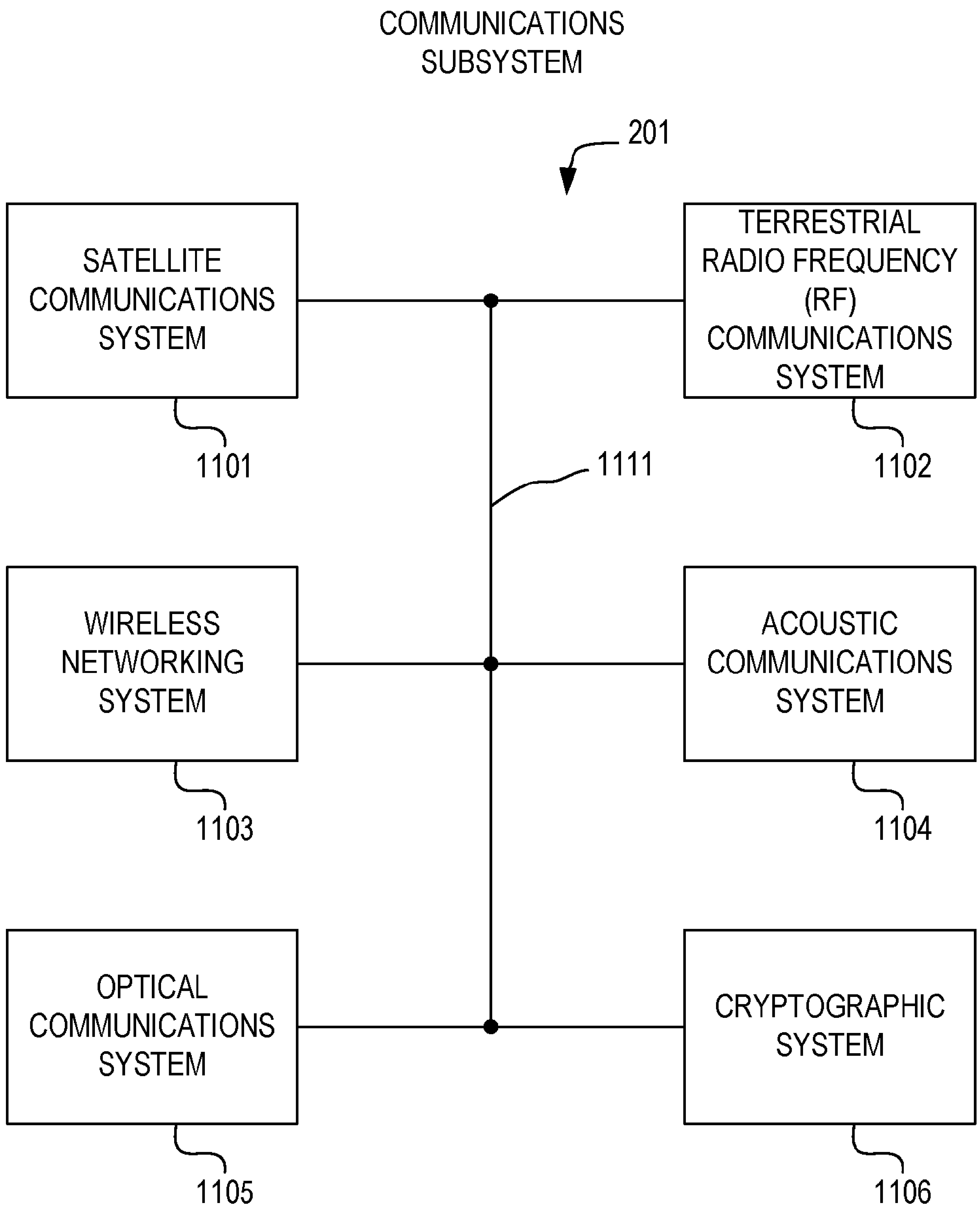
COMMUNICATIONS
SUBSYSTEM
201
SATELLITE
COMMUNICATIONS
SYSTEM
1101
TERRESTRIAL
RADIO FREQUENCY
(RF)
COMMUNICATIONS
SYSTEM
1102
1111
WIRELESS
NETWORKING
SYSTEM
1103
ACOUSTIC
COMMUNICATIONS
SYSTEM
1104
OPTICAL
COMMUNICATIONS
SYSTEM
1105
CRYPTOGRAPHIC
SYSTEM
1106

FIG. 11

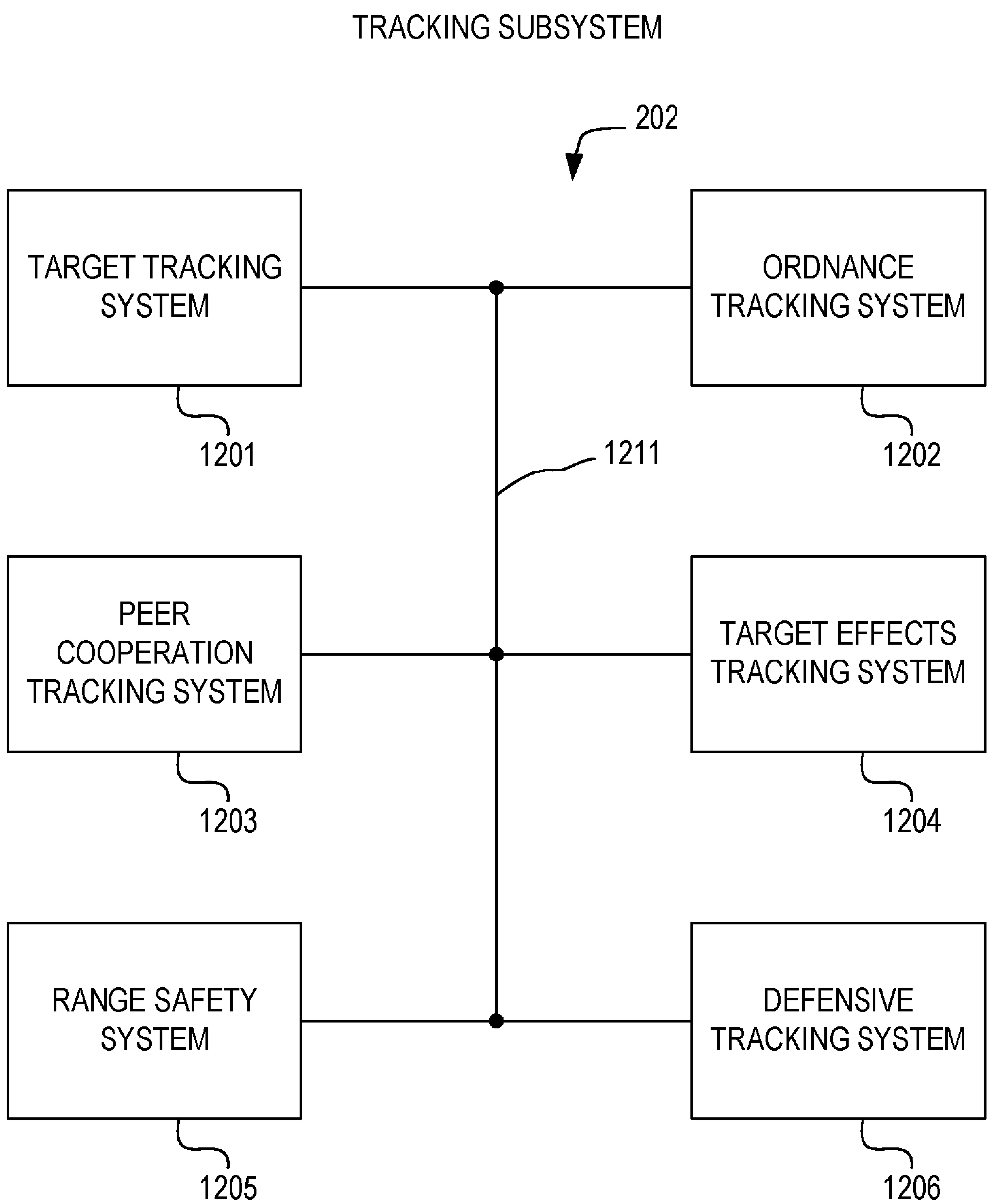
TRACKING SUBSYSTEM
202
TARGET TRACKING SYSTEM
1201
ORDNANCE TRACKING SYSTEM
1202
1211
PEER COOPERATION TRACKING SYSTEM
1203
TARGET EFFECTS TRACKING SYSTEM
1204
RANGE SAFETY SYSTEM
1205
DEFENSIVE TRACKING SYSTEM
1206

FIG. 12

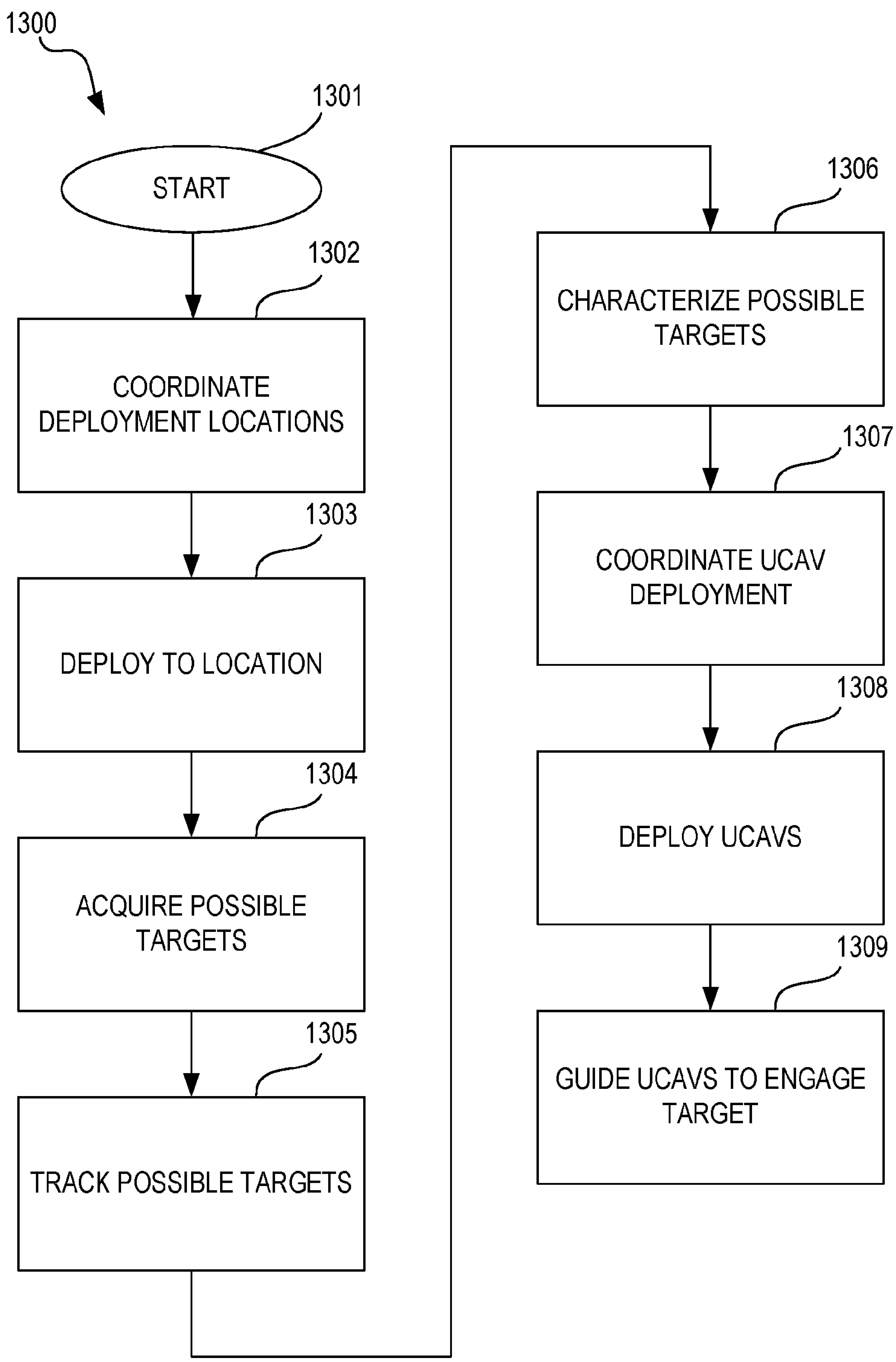
1300
1301
START
1302
COORDINATE DEPLOYMENT LOCATIONS
1303
DEPLOY TO LOCATION
1304
ACQUIRE POSSIBLE TARGETS
1305
TRACK POSSIBLE TARGETS
1306
CHARACTERIZE POSSIBLE TARGETS
1307
COORDINATE UCAV DEPLOYMENT
1308
DEPLOY UCAVS
1309
GUIDE UCAVS TO ENGAGE TARGET

FIG. 13

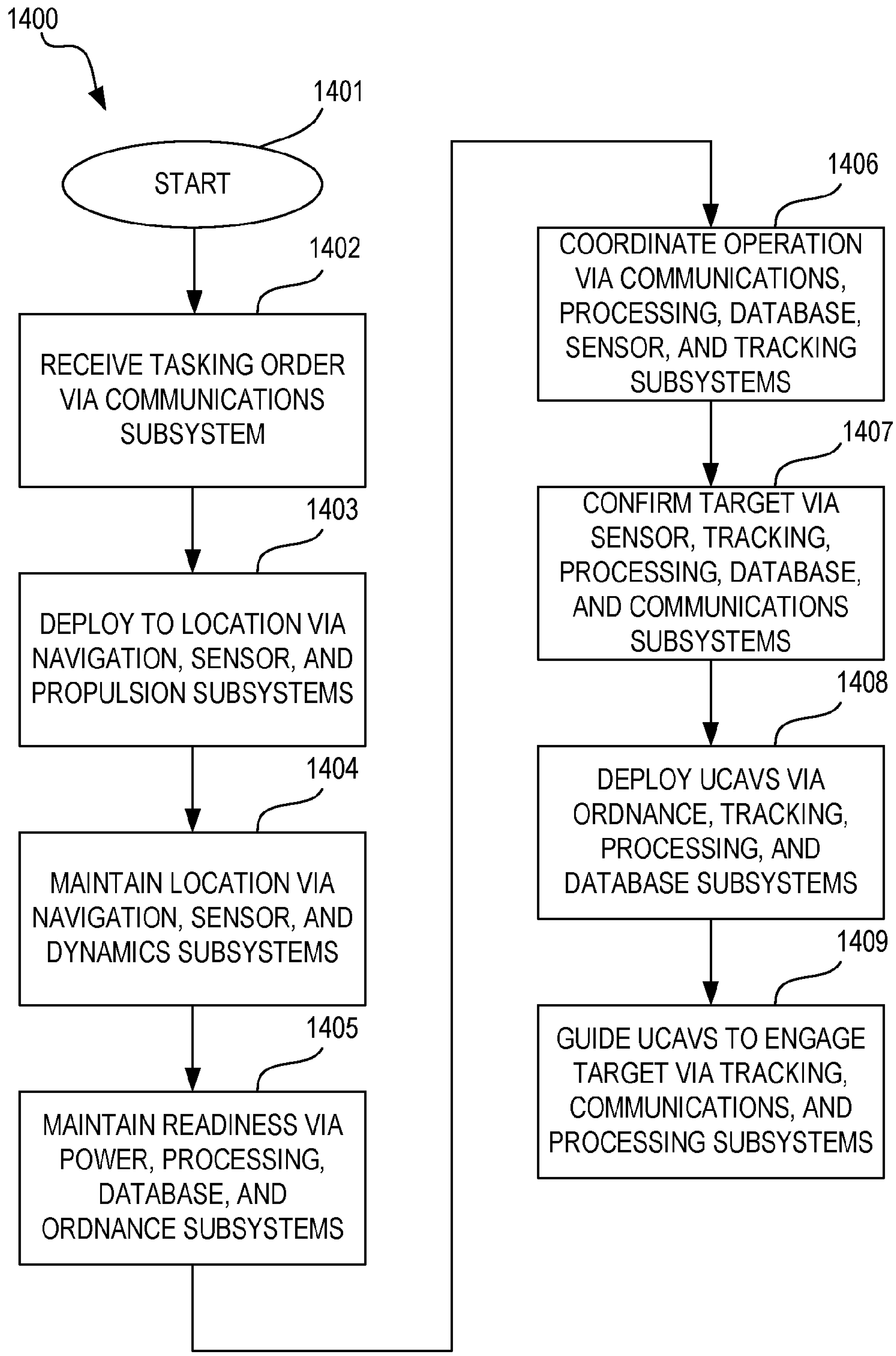
1400
1401
START
1402
RECEIVE TASKING ORDER VIA COMMUNICATIONS SUBSYSTEM
1403
DEPLOY TO LOCATION VIA NAVIGATION, SENSOR, AND PROPULSION SUBSYSTEMS
1404
MAINTAIN LOCATION VIA NAVIGATION, SENSOR, AND DYNAMICS SUBSYSTEMS
1405
MAINTAIN READINESS VIA POWER, PROCESSING, DATABASE, AND ORDNANCE SUBSYSTEMS
1406
COORDINATE OPERATION VIA COMMUNICATIONS, PROCESSING, DATABASE, SENSOR, AND TRACKING SUBSYSTEMS
1407
CONFIRM TARGET VIA SENSOR, TRACKING, PROCESSING, DATABASE, AND COMMUNICATIONS SUBSYSTEMS
1408
DEPLOY UCAVS VIA ORDNANCE, TRACKING, PROCESSING, AND DATABASE SUBSYSTEMS
1409
GUIDE UCAVS TO ENGAGE TARGET VIA TRACKING, COMMUNICATIONS, AND PROCESSING SUBSYSTEMS

FIG. 14

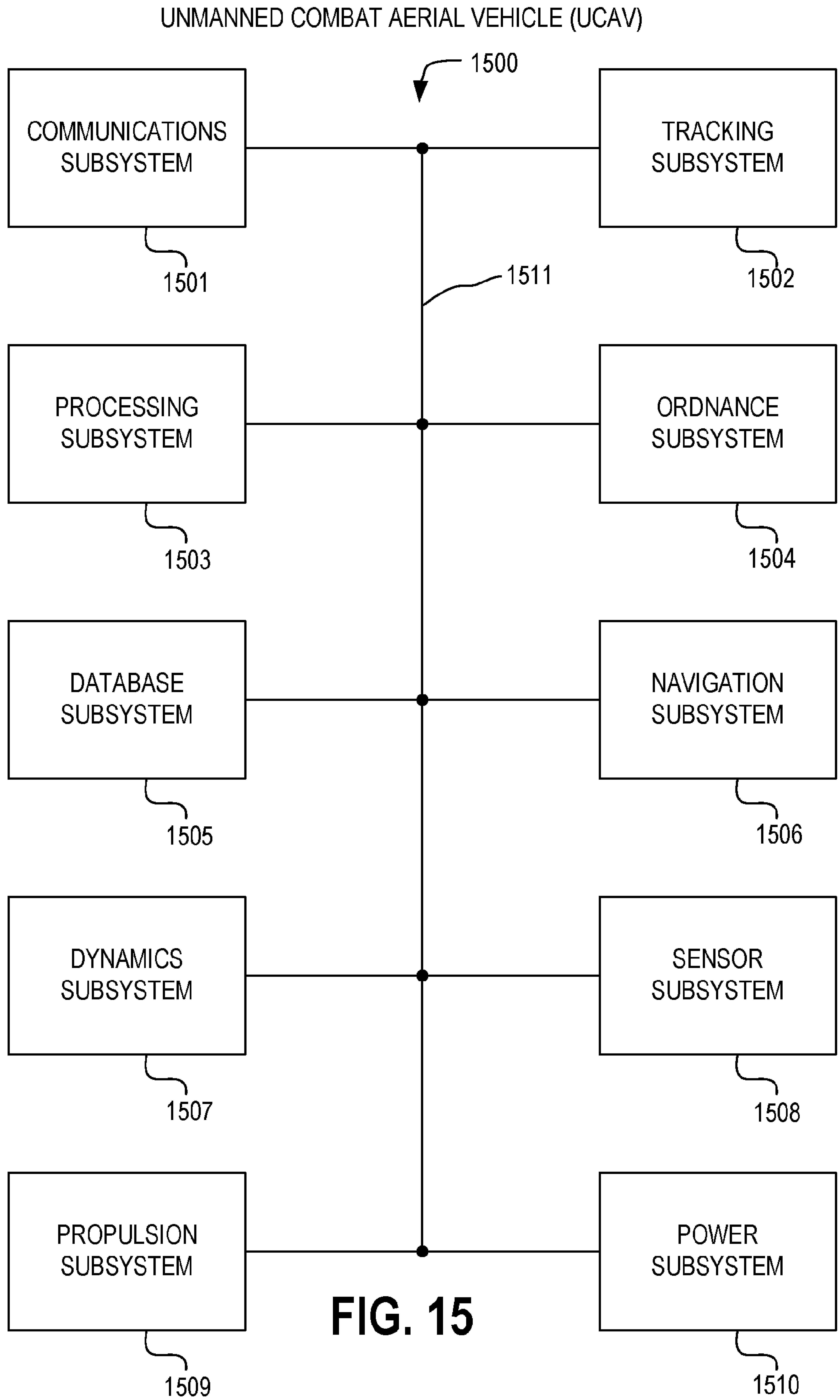
UNMANNED COMBAT AERIAL VEHICLE (UCAV)
1500
COMMUNICATIONS SUBSYSTEM
1501
TRACKING SUBSYSTEM
1502
1511
PROCESSING SUBSYSTEM
1503
ORDNANCE SUBSYSTEM
1504
DATABASE SUBSYSTEM
1505
NAVIGATION SUBSYSTEM
1506
DYNAMICS SUBSYSTEM
1507
SENSOR SUBSYSTEM
1508
PROPULSION SUBSYSTEM
1509
POWER SUBSYSTEM
1510

FIG. 15

AUTONOMOUS VESSEL FOR UNMANNED COMBAT AERIAL VEHICLE (UCAV) CARRIER OPERATIONS

CROSS-REFERENCE TO RELATED APPLICATION(S)

The present application is related to co-pending U.S. Patent Application entitled "STACKABLE UNMANNED AERIAL VEHICLE (UAV) SYSTEM AND PORTABLE HANGAR SYSTEM THEREFOR"; co-pending U.S. Patent Application entitled "ANTI-AIRCRAFT AUTONOMOUS UNDERSEA SYSTEM (AUS) WITH MACHINE VISION TARGET ACQUISITION"; co-pending U.S. Patent Application entitled "AERIALLY DISPERSIBLE MASSIVELY DISTRIBUTED SENSORLET SYSTEM"; and co-pending U.S. Application entitled "ARTIFICIAL INTELLIGENCE AUGMENTED REALITY COMMAND, CONTROL AND COMMUNICATIONS SYSTEM", the entirety of which are herein incorporated by reference.

BACKGROUND

Field of the Disclosure

The present disclosure relates generally to a vessel for defense of assets and, more particularly, to an unmanned autonomous vessel for defense of assets.

Background of the Disclosure

Assets, such as naval vessels, submarines, and other assets on, under, or near a surface of water, face threats, such as cruise missiles, anti-submarine ordnance, and anti-submarine ordnance delivery systems. As technology makes it easier and less expensive to construct and deploy systems that pose such threats, a corresponding increase in the availability and capability of technology to protect against such threats is needed.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure may be better understood, and its numerous features and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. **1** is an elevation view diagram illustrating an autonomous vessel in accordance with at least one embodiment.

FIG. **2** is a block diagram illustrating an autonomous vessel in accordance with at least one embodiment.

FIG. **3** is a block diagram illustrating a power subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **4** is a block diagram illustrating a propulsion subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **5** is a block diagram illustrating a dynamics subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **6** is a block diagram illustrating a sensor subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **7** is a block diagram illustrating a database subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **8** is a block diagram illustrating a navigation subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **9** is a block diagram illustrating a processing subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **10** is a block diagram illustrating an ordnance subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **11** is a block diagram illustrating a communications subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **12** is a block diagram illustrating a tracking subsystem of an autonomous vessel in accordance with at least one embodiment.

FIG. **13** is a flow diagram illustrating a method in accordance with at least one embodiment.

FIG. **14** is a flow diagram illustrating a method in accordance with at least one embodiment.

FIG. **15** is a block diagram illustrating an unmanned combat aerial vehicle (UCAV) in accordance with at least one embodiment.

The use of the same reference symbols in different drawings indicates similar or identical items.

DETAILED DESCRIPTION OF THE DRAWINGS

A stealth, autonomous vessel with a minimal surface footprint, and low observables (LO) characteristics, acting as a drone "carrier," is provided. Examples of roles of which the autonomous vessel is capable of performing include directing unmanned combat aerial vehicles (UCAVs) configured for anti-cruise-missile (anti-CM) and anti-anti-submarine-warfare (anti-ASW) asset ops. These systems can use swarm algorithms capable of creating "barrages." As an example, these systems can provide autonomous swarms of aerial mines. As another example, these systems can also be used as "rear guards" to subvert an enemy swarm, such as a hydrofoil or high-speed gunboat attack on a large scale. To illustrate, several UCAVs can be guided to a plurality of targets to provide a counter-swarm defense.

In accordance with at least one embodiment, an autonomous vessel provides protection against threats, for example, cruise missiles and anti-submarine-warfare (ASW) ordnance. The autonomous vessel comprises an ordnance subsystem. The ordnance subsystem comprises an ordnance magazine configured to store ordnance. An example of ordnance the autonomous vessel may store comprises ordnance deliverable via an UCAV. The ordnance is deployable against a target. The target can be autonomously identified by the autonomous vessel, or the target can be remotely identified by another asset, such as a UCAV, a peer UCAV, a peer autonomous vessel, a naval surface vessel, a naval subsurface vessel, an aircraft, or a spacecraft, such as a satellite. Alternatively, the target can be cooperatively identified by the autonomous vessel and at least one other asset or by a UCAV and at least one other asset.

In accordance with at least one embodiment, a plurality of autonomous vessels can cooperatively engage threats. For example, the plurality of autonomous vessels can coordinate with each other to observe, confirm, track, and engage threats by efficiently allocating resources, such as ordnance, among themselves. As one example, the plurality of autonomous vessels can create a "dome" of protection around assets, such as naval vessels or civilian vessels, or a "cloud" of protection between a threat and such an asset. As another example, one or more autonomous vessels can provide a low-maintenance deterrent against threats even in absence of proximate assets, for example, by providing a high-endurance deployed system ready to detect and engage threats, such as anti-submarine warfare (ASW) ordnance or a delivery system for delivering such ordnance. As an example, an autonomous vessel may be an autonomous surface vessel hosting UCAVs.

FIG. **1** is an elevation view diagram illustrating an autonomous vessel in accordance with at least one embodiment. Autonomous vessel **100** comprises a hull **113** having a bow **101** and a stern **112**. Hull **113** defines an opening **114** in an upper portion of autonomous vessel **100** to allow ordnance stowed in ordnance magazine **103** within autonomous vessel **100** to be delivered out of autonomous vessel **100** toward one or more targets. Autonomous vessel **100** comprises movable cover **102** to provide selective closure of opening **114**.

Autonomous vessel **100** comprises control surfaces, including lateral fore fin **111**, lateral aft fin **109**, upper vertical fin **108**, and lower vertical fin **110**. Upper vertical fin **108**, lower vertical fin **110**, and lateral aft fin **109** are coupled to an aft portion of hull **113**. Lateral fore fin **111** is coupled to a fore portion of hull **113**.

As illustrated, movable cover **102** is moved from opening **114**. With opening **114** open, ordnance from ordnance magazine **103** may be delivered from autonomous vessel **100**. As shown, UCAVs **104**, **105**, **115**, **116**, and **117** are examples of UCAVs deployable from ordnance magazine **103** through opening **114**.

In accordance with one embodiment, autonomous vessel **100** may be a flooded vessel having sealed modules within it to provide water protection individually to each subsystem, portion of a subsystem, or combination of subsystems in a module. As a flooded vessel, autonomous vessel **100** may comprise buoyant elements, such as air chambers, foam pieces, or other structures for providing buoyancy even in the flooded configuration. In accordance with another embodiment, autonomous vessel **100** may be a sealed vessel, maintaining a dry environment internally until movable cover **102** is opened. In accordance with another embodiment, a portion of autonomous vessel **100** may be a sealed vessel and another portion of autonomous vessel **100** may be a flooded vessel.

As one example, autonomous vessel **100** may be maintained in a submersed configuration, guided by communication with a peer network or a command and control system to surface for engaging targets. As another example, autonomous vessel **100** can be maintained in a surface configuration, allowing autonomous vessel **100** to utilize its own subsystems for target acquisition, target confirmation, and target tracking, as well as target engagement.

FIG. **2** is a block diagram illustrating an autonomous vessel in accordance with at least one embodiment. Autonomous vessel **100** comprises communications subsystem **201**, tracking subsystem **202**, processing subsystem **203**, ordnance subsystem **204**, database subsystem **205**, navigation subsystem **206**, dynamics subsystem **207**, sensor subsystem **208**, propulsion subsystem **209**, and power subsystem **210**. Each of such subsystems is coupled to at least another of such subsystems. In the illustrated example, the subsystems are coupled to each other via interconnect **211**. Communications subsystem **201** may be coupled to antennas, such as satellite antenna **212** and terrestrial antenna **213**. Other embodiments may be implemented with a subset of the above subsystems or with additional subsystems beyond the above subsystems or a subset thereof.

FIG. **3** is a block diagram illustrating a power subsystem of an autonomous vessel in accordance with at least one embodiment. Power subsystem **210** comprises voltage regulator **301**, load management system **302**, battery management system **303**, charging system **304**, battery **305**, and power source **306**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **311**.

As examples, power source **306** can be a solar power source, a wind power source, a wave power source, a hydrothermal power source, a chemical fuel power source, a nuclear power source, or another type of power source. Charging system **304** can be configured to charge battery **305** using power obtained from power source **306**. Battery management system can manage a battery state of battery **305** and can monitor charging and discharging of battery **305**. Load management system **302** can monitor power used by loads, such as other subsystems shown in FIG. **2**. Voltage regulator **301** can provide one or more regulated voltages to the loads.

FIG. **4** is a block diagram illustrating a propulsion subsystem of an autonomous vessel in accordance with at least one embodiment. Propulsion subsystem **209** comprises motor management system **401**, propulsion feedback sensors **402**, motor drive circuits **403**, station keeping motors **404**, trim motors **405**, and main motor **406**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **411**.

Main motor **406** can provide main propulsion of autonomous vessel **100**. Such main propulsion can allow autonomous vessel **100** to move to a deployment location. Such main propulsion can also allow autonomous vessel **100** to move in relation to other vessels, such as other instances of autonomous vessel **100** and a formation of naval vessels. Trim motors **405** can provide propulsive force to counteract force that would change the orientation of autonomous vessel **100** away from a desired orientation. As examples, trim motors **405** can compensate for forces that would tend to impart undesired pitch, yaw, and roll to autonomous vessel **100**. Station keeping motors **404** can provide propulsive force to counteract currents that would cause autonomous vessel **100** to drift away from its deployment location. As examples, station keeping motors **404** can be oriented along a plurality of axes, such as x, y, and z orthogonal axes, to allow station keeping in three dimensions. Motor drive circuits **403** are coupled to main motor **406**, trim motors **405**, and station keeping motors **404** to provide electrical motor drive signals to drive such motors. Power for the electrical motor drive signals can be obtained from power subsystem **210**. Propulsion feedback sensors **402** can monitor the propulsion provided by the motors of propulsion subsystem **209**. As an example, propulsion feedback sensors **402** can include pressure sensors to measure pressures produced by movement of water by propulsion system elements. As another example, propulsion feedback sensors **402** can include accelerometers to measure acceleration provided by propulsion system elements. Motor management system **401** can use information from propulsion feedback sensors **402** to cause motor drive circuits **403** to drive main motor **406**, trim motors **405**, and station keeping motors **404** to provide desired propulsion.

FIG. **5** is a block diagram illustrating a dynamics subsystem of an autonomous vessel in accordance with at least one embodiment. Dynamics subsystem **207** comprises dynamics management system **501**, dynamics sensors **502**, dynamics surface positioning actuators **503**, station-keeping motor controller **504**, trim motor controller **505**, and main motor controller **506**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **511**.

Dynamics sensors **502** sense dynamic forces and responsiveness of autonomous vessel **100** to such dynamic forces. Examples of dynamic sensors **502** include pressure sensors, strain gauges, and fluid dynamics sensors. Dynamics management system **501** uses the sensed data from dynamics sensors **502** to provide dynamics control signals to dynamics surface positioning actuators **503**, to main motor controller **506**, to trim motor controller **505**, and to station-keeping motor controller **504**. Dynamics surface positioning actuators **503** can comprise, for example, actuators to orient hydrodynamic surfaces of autonomous vessel **100** to adjust the responsiveness of autonomous vessel **100** to hydrodynamic forces exerted upon it. Main motor controller **506**, trim motor controller **505**, and station-keeping motor controller **504** can provide dynamics control signals to adjust the operation of main motor **406**, trim motors **405**, and station keeping motors **404**, respectively, as dictated by dynamics management system **501** in response to dynamics sensor data from dynamics sensors **502**.

FIG. **6** is a block diagram illustrating a sensor subsystem of an autonomous vessel in accordance with at least one embodiment. Sensor subsystem **208** comprises target sensors **601**, surface traffic sensors **602**, fixed obstacle sensors **603**, subsurface traffic sensors **604**, imaging sensors **605**, and science sensors **606**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **611**.

Target sensors **601** include sensors suitable for sensing a target suitable for engagement with ordnance subsystem **204** of autonomous vessel **100**. Examples of target sensors **601** include a monostatic radar, a bistatic radar receiver, a bistatic radar transmitter, an infrared sensor, and a passive acoustic sensor. Surface traffic sensors **602** include sensors suitable for sensing traffic of autonomous vessels on a surface of water in which autonomous vessel **100** operates. Examples of surface traffic sensors **602** include a monostatic radar, a bistatic radar receiver, a bistatic radar transmitter, an infrared sensor, an active acoustic sensor, and a passive acoustic sensor. Fixed obstacle sensors **603** include sensors suitable for sensing fixed obstacles. Examples of fixed obstacle sensors **603** include a monostatic radar, a bistatic radar receiver, a bistatic radar transmitter, an infrared sensor, an active acoustic sensor, a passive acoustic sensor, and a depth profiler. Subsurface traffic sensors **604** include sensors suitable for sensing traffic of subsurface vessels below a surface of water in which autonomous vessel **100** operates. Examples of subsurface traffic sensors **604** include an active acoustic sensor, a passive acoustic sensor, and a magnetic sensor. The magnetic sensor may include, for example, a magnetometer or a magnetic anomaly detector. Imaging sensors **605** include sensors capable of obtaining images. Examples of imaging sensors **605** include visible still cameras, visible video cameras, infrared cameras, ultraviolet cameras, star tracking cameras, and other cameras.

Imaging sensors **605** can comprise sensors such as side scan sonar (SSS), synthetic aperture sonar (SAS), multibeam echosounders (MBES), imaging sonar, sub-bottom profiler (SBP), video cameras, still cameras, infrared cameras, multispectral cameras, and other types of imaging sensors. Science sensors **606** can comprise sensors such as conductivity, temperature, and depth (CTD) sensors, conductivity and temperature (CT) sensors, fluorometers, turbidity sensors, sound velocity sensors, beam attenuation meters, scattering meters, transmissometers, and magnetometers.

FIG. **7** is a block diagram illustrating a database subsystem of an autonomous vessel in accordance with at least one embodiment. Database subsystem **205** comprises target database **701**, surface traffic database **702**, oceanographic database **703**, subsurface traffic database **704**, peer network database **705**, and science database **706**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **711**.

Target database **701** is a database for storing information characterizing potential targets and other information useful for distinguishing non-targets from targets. As examples, target database **701** may include information such as identification friend or foe (IFF) information, radar signature information, infrared signature information, and acoustic signature information as may pertain to aircraft. Surface traffic database **702** is a database for storing information characterizing potential surface traffic. As examples, surface traffic database **702** may include information such as radar signature information, infrared signature information, and acoustic signature information as may pertain to surface vessels. Oceanographic database **703** is a database for storing information characterizing physical features of the operating environment, such as an ocean, of autonomous vessel **100**. As examples, oceanographic database **703** may include information as to ocean floor topography, ocean currents, islands, coastlines, and other features. Subsurface traffic database **704** is a database for storing information characterizing potential subsurface traffic. As examples, subsurface traffic database **704** may include information such as acoustic signature information as may pertain to subsurface vessels. Peer network database **705** is a database for storing information characterizing a relationship of autonomous vessel **100** to other instances of autonomous vessel **100** capable of operating cooperatively as peers with autonomous vessel **100**. As examples, subsurface traffic database **704** may include information as to locations of peers, sensor parameters of peers, ordnance capabilities of peers, readiness of peers, and other properties of peers. Science database **706** is a database for storing information of a scientific nature, such as water temperature, water salinity, water conductivity, water density, water turbidity, air temperature, barometric pressure, sky conditions, and other information descriptive of conditions of the environment within which surface vessel **100** operates.

FIG. **8** is a block diagram illustrating a navigation subsystem of an autonomous vessel in accordance with at least one embodiment. Navigation subsystem **206** comprises satellite based navigation system **801**, inertial navigation system **802**, acoustic navigation system **803**, image based navigation system **804**, magnetic navigation system **805**, and pressure based navigation system **806**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **811**.

Satellite based navigation system **801** can comprise, for example, a Global Navigation Satellite System (GLONASS) receiver and a Global Positioning System (GPS) receiver, which may include a Selective Availability/Anti-Spoofing Module (SAASM), a precise pseudo-random code (P-code) module, and an encrypted precise pseudo-random code (Y-code) module. Inertial navigation system **802** can comprise an inertial navigation sensor (INS) and an inertial measurement unit (IMU), which can comprise at least one of an accelerometer, a gyroscope, and a magnetometer.

Acoustic navigation system **803** can comprise, for example, Ultra Short Baseline (USBL) system, Long Baseline (LBL) system, a Doppler Velocity Logger (DVL), and an acoustic tracking transponder. Magnetic navigation system **805** can comprise, for example, a compass. Pressure based navigation system **806** can comprise, for example, an altimeter and a pressure sensor.

FIG. **9** is a block diagram illustrating a processing subsystem of an autonomous vessel in accordance with at least one embodiment. Processing subsystem **203** comprises processor **901**, sensor fusion subsystem **902**, object detection and analysis subsystem **903**, reasoning and planning subsystem **904**, control and autonomy subsystem **905**, and explainability and transparency subsystem **906**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **911**. In a particular implementation, the processing subsystem is configured to provide autonomous control of the autonomous vessel **100**.

Processor **901** is a data processor for processing information within autonomous vessel **100**. Processor **901** can cooperate with subsystems of processing subsystem **203**, such as sensor fusion subsystem **902**, object detection and analysis subsystem **903**, reasoning and planning subsystem **904**, control and autonomy subsystem **905**, and explainability and transparency subsystem **906**. As one example, processing subsystem **203** can be implemented to utilize heterogeneous computing, wherein the different elements of processing subsystem **203** are implemented using different configurations of processor circuits, in accordance with at least one embodiment. As another example, a homogeneous computing system comprising similar configurations of processor circuits, such as a symmetric multiprocessor (SMP) system, can be used to implement processing subsystem **203**.

Sensor fusion subsystem **902** processes sensor data obtained by sensors, such as sensors of sensor subsystem **208**. Sensor data can be obtained from sensors local to autonomous vessel **100** or from remote sensors located elsewhere, for example, on other instances of autonomous vessel **100**, on other vessels, or on other platforms, such as satellites, aircraft, or fixed locations. Sensor fusion subsystem **902** provides fidelity enhancement with multi-sensor feeds. As an example, sensor fusion subsystem **902** compares sensor data from multiple sensors to cross-validate the sensor data. The sensor data being cross-validated can be homogeneous, having been obtained from different instances of a similar type of sensor, can be heterogeneous, having been obtained from different types of sensors, or can have homogeneous and heterogeneous aspects, having been obtained from different instances of a similar type of sensor for each of a plurality of different types of sensors.

Sensor fusion subsystem **902** provides noise reduction and bad data identification via deep artificial neural networks (ANNs). Deep artificial neural networks are configured to recognize spurious data that, if relied upon, could lead to improper decision making. The deep artificial neural networks can acquire knowledge that can be stored within the adaptive elements of the deep artificial neural networks, and that acquired knowledge can be used for subsequent decision making. As an example, as a wide range of sensor data is obtained over time, sensor fusion subsystem **902** can learn to distinguish between, as examples, civilian aircraft, friendly military aircraft, and hostile military aircraft.

Sensor fusion subsystem **902** provides automated feature construction and evolution. By processing sensor data to identify features of a potential target that can be recognized from the information provided by the sensor data and adaptively modifying the processing of the sensor data over time to improve the identification of such features, feature recognition provided by sensor fusion subsystem **902** can improve identification of actual targets from among potential targets.

Sensor fusion subsystem **902** can combine augmented reality (AR) with virtual reality (VR) and predictive algorithms to facilitate application of information obtained from sensors to create an easily comprehensible presentation of a situation. For example, sensor fusion subsystem **902** can effectively filter out extraneous information, such as weather conditions and countermeasure effects, to provide a clear presentation of a target. The presentation of the target can be made with respect to autonomous vessel **100**, for example, with respect to the engagement range of the ordnance of ordnance subsystem **204** of autonomous vessel **100**.

Object detection and analysis subsystem **903** utilizes machine vision techniques to process sensor data to recognize an object the sensor data represents. Object detection and analysis subsystem **903** provides multi-spectral, cross-sensor analysis of sensor data, correlating sensor data of different types and of different sensors to assemble an accurate characterization of a detected object. Object detection and analysis subsystem **903** can perform new object discovery, utilizing unsupervised learning, which can identify the presence of new types of objects not previously known to exist or not previously having been identifiable based on previous processing of sensor data. Object detection and analysis subsystem **903** can provide a comprehensive vision of detectable objects and can apply ontologies to characterize such objects and their potential significance in a battlespace.

Reasoning and planning subsystem **904** can apply strategy generation techniques and strategy adaptation techniques to develop and adapt a strategy for protecting autonomous vessel **100** and other assets in concert with which autonomous vessel **100** may be deployed, for example, other instances of autonomous vessel **100** and naval vessels that may be protected by autonomous vessel **100**. Reasoning and planning subsystem **904** can apply reality vectors to provide a thought-vector-like treatment of a real state of autonomous vessel **100** and its surroundings. Reasoning and planning subsystem **904** can apply reinforcement learning and evolutionary processes to accumulate knowledge during the course of its operation.

Control and autonomy subsystem **905** utilizes platforms to transform a large amount of data into situational awareness. For example, control and autonomy subsystem **905** can utilize simulation engines to transform data, such as sensor data and object information obtained from sensor data, into an understanding of the situation faced by autonomous vessel **100** that allows control and autonomy subsystem **905** to initiate action, such as engagement of a target using the ordnance of ordnance subsystem **204**. Control and autonomy subsystem **905** can utilize reinforcement learning applications to evolve controllers, which can be used to autonomously control autonomous vessel **100**. Control and autonomy subsystem **905** can utilize swarm constrained deep learning for distributed decision making.

Control and autonomy subsystem **905** can coordinate flight of a plurality of UCAVs, for example, to create a swarm of UCAVs. The swarm parameters can be configured to assure safe separation of UCAVs from each other but a swarm configuration of appropriate density to provide interception of airborne threats. As an example, the swarm parameters can be selected to provide an evenly spaced distribution of UCAVs. As another example, the swarm parameters can be selected to provide a weighted distribution of UCAVs. The weighted distribution can have a greater density of UCAVs over a space in which a threat is expected to have a higher likelihood of flying and a lesser density of UCAVs over another space in which a threat is expected to have a lower likelihood of flying.

Control and autonomy subsystem **905** can interact with other subsystems, such as sensor subsystem **208** and tracking subsystem **202** to adaptively control the operation of the UCAVs via communications subsystem **201**.

Explainability and transparency subsystem **906** can perform analysis and observation by applying natural language processing (NLP) and natural language generation (NLG) to produce natural language reports. Explainability and transparency subsystem **906** can perform hypothesis validation, enabling autonomous research to be performed by autonomous vessel **100**. Explainability and transparency subsystem **906** can perform automated ontology discovery, allowing autonomous vessel **100** to recognize and respond to threats that do not fit within an existing knowledge base of threats.

FIG. **10** is a block diagram illustrating an ordnance subsystem of an autonomous vessel in accordance with at least one embodiment. Ordnance subsystem **204** comprises ordnance use controller **1001**, ordnance launch controller **1002**, ordnance safety system **1003**, ordnance readiness controller **1004**, ordnance **1005**, and ordnance security controller **1006**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **1011**. Ordnance safety system **1003** comprises environmental subsystem **1007**.

Ordnance **1005** may, for example, be an UCAV carrying an explosive payload. For example, the explosive payload may comprise an explosive charge in an unprefragmented housing, an explosive charge in a prefragmented housing, thermobaric explosive payload, an electromagnetic explosive payload, or another type of explosive payload. Ordnance **1005** may comprise a charging subsystem **1009**, which may, for example, cooperate with power subsystem **210** to allow charging (and subsequent recharging) of ordnance **1005**. As an example, ordnance **1005** in the form of a UCAV can include a rechargeable battery to power a propulsion system, such as a propeller system. Charging subsystem **1009** can charge the rechargeable battery of the UCAV. The UCAV can be deployed on multiple sorties, being recharged from time to time to continue to power the propulsion system over the multiple sorties. The rechargeable battery of the UCAV can also power other systems of the UCAV besides the propulsion system.

Ordnance security controller **1006** can operate to maintain security of ordnance **1005**. As an example, ordnance security controller **1006** can be configured to detect tampering with autonomous vessel **100** that poses a security risk to ordnance **1005**. Ordnance security controller **1006** can be configured, for example, to temporarily or permanently disable ordnance **1005** in response to a detected security risk.

Ordnance safety system **1003** can monitor conditions affecting safety of ordnance **1005**. As an example, ordnance safety system **1003** can include environmental subsystem **1007**. Environmental subsystem **1007** can monitor environmental conditions to which ordnance **1005** is exposed. Based on the monitored environmental conditions, ordnance safety system **1003** can determine whether the safety of ordnance **1005** has been compromised. In the event of the safety has been compromised, ordnance safety system **1003** can communicate a warning to other components of ordnance subsystem **204**, such as to ordnance readiness controller **1004**, ordnance use controller **1001**, and ordnance launch controller **1002** to warn of potential safety risks concerning ordnance **1005**. The other components can perform risk mitigation actions, such as inhibiting launch of ordnance **1005**, rendering ordnance **1005** inert, or jettisoning ordnance **1005**. The jettison process can be coordinated with other subsystems, such navigation subsystem **206**, sensor subsystem **208**, and database subsystem **205**, to command self-destruction of ordnance **1005** after ordnance **1005** has been jettisoned to a safe location.

Ordnance readiness controller **1004** manages readiness of ordnance **1005** for use. Ordnance readiness controller **1004** can receive ordnance security information from ordnance security controller **1006**, ordnance safety information from ordnance safety system **1003**, and ordnance self-test information from ordnance **1005**. Ordnance readiness controller **1004** can use such information to determine an overall readiness of ordnance **1005** for use.

Ordnance use controller **1001** manages confirmation of authority to use ordnance **1005**. For example, ordnance use controller can receive a message via communications subsystem **1101**, which may have been decrypted via cryptographic system **1106**, to authorize the use of ordnance **1005** or alternatively, to delegate the authority to use ordnance **1005** to processing subsystem **203**, allowing autonomous vessel **100** to use ordnance **1005** autonomously.

Ordnance launch controller **1002** controls a launch sequence of ordnance **1005** when ordnance use controller **1001** has confirmed authority to use ordnance **1005**. Ordnance launch controller **1002** monitors conditions for a safe launch of ordnance **1005** and is able to inhibit launch when such conditions are not met and to proceed with launch when such conditions are met.

FIG. **11** is a block diagram illustrating a communications subsystem of an autonomous vessel in accordance with at least one embodiment. Communications subsystem **201** comprises satellite communications system **1101**, terrestrial radio frequency (RF) communications system **1102**, wireless networking system **1103**, acoustic communications system **1104**, optical communications system **1105**, and cryptographic system **1106**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **1111**.

Satellite communications system **1101** can comprise, for example, a Fleet Satellite Communications System (FLTSATCOM) transceiver, an Ultra High Frequency (UHF) Follow-On (UFO) transceiver, a Mobile User Objective System (MUOS) transceiver, and a commercial satellite transceiver, such as an IRIDIUM satellite transceiver. Terrestrial RF communications system **1102** can comprise, for example, a terrestrial RF modem operating on one or more bands, such as a High Frequency (HF) band, a Very High Frequency (VHF) band, an Ultra High Frequency (UHF) band, and a microwave (μwave) band. Wireless networking system **1103** can comprise a WIFI wireless network transceiver (WIFI is a registered trademark of Wi-Fi Alliance), a BLUETOOTH wireless network transceiver (BLUETOOTH is a registered trademark of Bluetooth SIG, Inc.), a WIGIG wireless network transceiver (WIGIG is a registered trademark of Wi-Fi Alliance), and another type of wireless network transceiver. Acoustic communications system **1104** can comprise an acoustic modem. Optical communications system **1105** may comprise, for example, a blue/green laser communications system.

Communications subsystem **201** can communicate, for example, with a plurality of UCAVs deployed by autonomous vessel **100**. As an example, communications subsystem **201** can use wireless networking system **1103** to create a communications network with the plurality of UCAVs. As one example, such as communications network can be a mesh network, wherein the plurality of UCAVs can relay messages amongst themselves to extend the networking range. The relayed messages may originate, for example, from autonomous vessel **100** or from one of the plurality of UCAVs. The relayed messages may be destined, for example, for autonomous vessel **100** or one of the plurality of UCAVs.

FIG. **12** is a block diagram illustrating a tracking subsystem of an autonomous vessel in accordance with at least one embodiment. Tracking subsystem **202** comprises target tracking system **1201**, ordnance tracking system **1202**, peer cooperation tracking system **1203**, target effects tracking system **1204**, range safety system **1205**, and defensive tracking system **1206**. Each of such elements is coupled to at least another of such elements. In the illustrated example, the elements are coupled to each other via interconnect **1211**.

Target tracking system **1201** provides an ability to track a target acquired by sensor subsystem **208**. Peer cooperation tracking system **1203** provides an ability to cooperate with the tracking subsystems of other instances of autonomous vessel **100**, allowing such other instances to act as peers in tracking. Defensive tracking system **1206** allows autonomous vessel **100** to track threats against itself. Ordnance tracking system **1202** tracks ordnance **1005** after ordnance **1005** is launched to engage a target. Target effects tracking system **1204** tracks the effects of ordnance **1005** on the target. Range safety system **1205** obtains ordnance trajectory information as to the trajectory of ordnance **1005**, for example, from ordnance tracking system **1202**. Range safety system **1205** can take protective action, for example, commanding destruction of ordnance **1005**, if ordnance **1005** fails to maintain its intended trajectory.

FIG. **13** is a flow diagram illustrating a method in accordance with at least one embodiment. Method **1300** begins at block **1301** and continues to block **1302**. At block **1302**, autonomous vessel **100** coordinates deployment locations. A deployment location of autonomous vessel **100** can be coordinated with other locations of other assets, such as locations of other instances of autonomous vessel **100** and locations of naval vessels. Autonomous vessel **100** can use communications subsystem **201** to communicate with such other instances of autonomous vessel **100** and such naval vessels. As an example, the coordination of deployment locations can provide force protection not only for autonomous vessel **100** itself and any peers that may accompany it, but also for a group of naval vessels it and any peers accompany. The protection can be provided when the naval vessels are at anchor and when the naval vessels are underway. From block **1302**, method **1300** continues to block **1303**. At block **1303**, autonomous vessel **100** deploys itself to its deployment location. As an example, the deployment location may be a fixed location, or, as another example, the deployment location may be a point along a path of multiple locations among which autonomous vessel **100** is configured to move. As one example, autonomous vessel **100** may be configured to move from one deployment location to another deployment location. As another example, autonomous vessel **100** may be configured to move to a deployment location having a defined relationship (e.g., a standoff distance) to other assets, such as peers and naval vessels, and to maintain the defined relationship by moving in a similar direction and at a similar speed as the other assets. From block **1303**, method **1300** continues to block **1304**. At block **1304**, autonomous vessel **100** acquires possible targets. The possible targets can be acquired based on information obtained from at least one sensor, such as at least one sensor of sensor subsystem **208**, at least one sensor of a sensor subsystem of a peer autonomous vessel, or at least one sensor of another asset, such as a naval surface vessel, a naval subsurface vessel, an aircraft, or a spacecraft. From block **1304**, method **1300** continues to block **1305**. At block **1305**, autonomous vessel **100** tracks possible targets. The tracking of possible targets can be performed, for example, by tracking subsystem **202**. From block **1305**, method **1300** continues to block **1306**. At block **1306**, autonomous vessel **100** characterizes possible targets. As an example, the characterization of possible targets can be performed by processing subsystem **203** with reference to data stored in database subsystem **205**. From block **1306**, method **1300** continues to block **1307**. At block **1307**, autonomous vessel **100** coordinates deployment of UCAVs from autonomous vessel **100**. As an example, processing subsystem **203** can coordinate deployment of UCAVs based on information obtained from tracking subsystem **202** with reference to data stored in database subsystem **205**. From block **1307**, method **1300** continues to block **1308**. At block **1308**, autonomous vessel **100** deploys UCAVs. As an example, autonomous vessel **100** can deploy UCAVs in a swarm configuration of sufficient density to effectively engage a target attempting to fly through the swarm configuration. From block **1308**, method **1300** continues to block **1309**. At block **1309**, autonomous vessel **100** guides the UCAVs to engage the target. As an example, the ordnance can be tracked to the target by tracking subsystem **202**.

FIG. **14** is a flow diagram illustrating a method in accordance with at least one embodiment. Method **1400** begins at block **1401** and continues to block **1402**. At block **1402**, autonomous vessel **100** receives a tasking order via communications subsystem **201**. The tasking order may, for example, be received from an authority competent to authorize the employment of the ordnance of ordnance subsystem **204**. As an example, the tasking order may be communicated in encrypted form, and cryptographic system **1106** of communications subsystem **201** can decrypt the encrypted tasking order. From block **1402**, method **1400** continues to block **1403**. At block **1403**, autonomous vessel **100** deploys to a deployment location via navigation subsystem **206**, sensor subsystem **208**, and propulsion subsystem **209**. The deployment location may be a fixed location or a location relative to other objects, which need not be fixed and may be moving. The other objects may be, for example, peers or naval vessels. Autonomous vessel **100** may move in formation with such objects. From block **1403**, method **1400** continues to block **1404**. At block **1404**, autonomous vessel **100** maintains its location via navigation subsystem **206**, sensor subsystem **208**, and dynamics subsystem **207**. The location may be a fixed location or a relative location in relation to other objects, which may be moving. From block **1404**, method **1400** continues to block **1405**. At block **1405**, autonomous vessel **100** maintains its readiness via power subsystem **210**, processing subsystem **203**, database subsystem **205**, and ordnance subsystem **204**. As examples, power subsystem **210** can obtain power from power source **306** to be used by charging system **304** to maintain a desired state of charge of battery **305**, ordnance subsystem **204** can use ordnance readiness controller **1004** to assure readiness of ordnance **1005**, and processing subsystem **203** and database subsystem **205** can monitor a state of autonomous vessel **100** and its surroundings to assure the state is consistent with readiness. From block **1405**, method **1400** continues to block **1406**. At block **1406**, autonomous vessel **100** coordinates operation via communications subsystem **201**, processing subsystem **203**, database subsystem **205**, sensor subsystem **208**, and tracking subsystem **202**. As examples, autonomous vessel **100** can coordinate its operation with peer autonomous vessels and other craft, such as naval vessels. For example, autonomous vessel **100** can coordinate the portions of airspace and water it monitors using sensor subsystem **208** with portions of airspace and water its peers monitor with their respective sensor subsystems. As another example, autonomous vessel **100** can coordinate its operation with other assets, such as naval surface vessels, naval subsurface vessels, aircraft, and spacecraft. From block **1406**, method **1400** continues to block **1407**. At block **1407**, autonomous vessel **100** confirms a target via sensor subsystem **208**, tracking subsystem **202**, processing subsystem **203**, database subsystem **205**, and communications subsystem **201**. As an example, autonomous vessel **100** can analyze, using processing subsystem **203**, data from sensor subsystem **208** and tracking subsystem **202**, with reference to stored data of database subsystem **205**, to obtain a confirmation that a possible target is an actual target. As an example, autonomous vessel **100** can communicate with peers or other assets via communications subsystem **201** to assist in the confirmation of the target. From block **1407**, method **1400** continues to block **1408**. At block **1408**, autonomous vessel **100** deploys UCAVs via ordnance subsystem **204**, tracking subsystem **202**, processing subsystem **203**, and database subsystem **205**. As an example, ordnance launch controller **1002** consults ordnance use controller **1001** to confirm permission for use of ordnance **1005**, consults ordnance security controller **1006** to confirm security of ordnance **1005**, consults ordnance safety system **1003** to confirm safety of ordnance **1005** for launch, and consults ordnance readiness controller **1004** to confirm readiness of ordnance **1005** for launch. Upon proper confirmations, ordnance launch controller **1002** launches UCAVs carrying ordnance. From block **1408**, method **1400** continues to block **1409**. At block **1409**, autonomous vessel **100** guides one or more UCAVs to one or more targets via tracking subsystem **202**, communications subsystem **201**, and processing subsystem **203**. As an example, autonomous vessel **100** can guide one or more UCAVs to one or more targets by itself or in coordination with other assets, for example, via communications subsystem **201**.

FIG. **15** is a block diagram illustrating an unmanned combat aerial vehicle (UCAV) in accordance with at least one embodiment. UCAV **1500** comprises communications subsystem **1501**, tracking subsystem **1502**, processing subsystem **1503**, ordnance subsystem **1504**, database subsystem **1505**, navigation subsystem **1506**, dynamics subsystem **1507**, sensor subsystem **1508**, propulsion subsystem **1509**, and power subsystem **1510**. Each of such subsystems is coupled to at least another of such subsystems. In the illustrated example, the subsystems are coupled to each other via interconnect **1511**. Other embodiments may be implemented with a subset of the above subsystems or with additional subsystems beyond the above subsystems or a subset thereof.

Communication subsystem **1501** of UCAV **1500** can be used, for example, to communicate with other UCAVs and, for example, to communicate with autonomous vessel **100**. Such communication can be used, for example, to coordinate flight of UCAVs. Examples of coordination include an ability to configure the flight of UCAVs into a defensive swarm and an ability to configure UCAVs to engage, in a serial, parallel, or combined parallel and serial manner, targeted threats. Such targeted threats can include, for example, airborne threats and seaborne threats. Examples of airborne threats include cruise missiles and ASW ordnance and delivery systems. Examples of seaborne threats include hydrofoils and high-speed gunboats.

Tracking subsystem **1502** of UCAV **1500** can provide tracking of UCAV **1500** relative to autonomous vessel **100**, tracking of other UCAVs relative to UCAV **1500**, and tracking of potential targets and confirmed targets. Tracking subsystem can utilize radar, radio frequency (RF), optical, acoustic, and other types of tracking components.

Processing subsystem **1503** of UCAV **1500** can send and receive information from other subsystems of UCAV **1500**. Processing subsystem **1503** can obtain data from database subsystem **1505** and can use the data obtained to characterize the information received from other subsystems of UCAV **1500**. Processing subsystem **1503** can also send and receive information to and from other entities, such as other UCAVs and autonomous vessel **100**, via communication subsystem **1501**. Processing subsystem **1503** of UCAV **1500** can be configured to communicate with another UCAV. The first and second UCAVs can use either or both of their respective processing subsystems to plan cooperative engagement of a confirmed target by at least one of the UCAVs in coordination with the other UCAV. The first and second UCAVs can be configured to deploy cooperatively with additional UCAVs to form an aerial minefield employable against the confirmed target. In a particular implementation, a plurality of UCAVs cooperatively develop an engagement plan for at least one of the plurality of UCAVs to expend ordnance against the confirmed target.

Ordnance subsystem **1504** of UCAV **1500** can provide elements to defeat targets to be engaged by UCAV **1500**. As examples, ordnance subsystem **1504** may comprise an explosive charge in an unprefragmented housing, an explosive charge in a prefragmented housing, thermobaric explosive payload, an electromagnetic explosive payload, or another type of explosive payload. As another example, ordnance subsystem **1504** may comprise a kinetic payload to impact matter with a target. As another example, ordnance subsystem **1504** may comprise a non-explosive electromagnetic payload, such as a laser or high-energy RF (HERF), payload to deliver intense electromagnetic energy to a target. In accordance with at least one embodiment, ordnance subsystem **1504** can provide an "aerial mine" capability to UCAV **1500**, with other subsystems of UCAV **1500** positioning UCAV **1500** in an expected path of a target and ordnance subsystem **1504** engaging the target in proximity to UCAV **1500**. The ordnance is deliverable by one or more UCAVs against one or more targets. At least a portion of the ordnance is expendable against the one or more targets.

Navigation subsystem **1506** of UCAV **1500** allows UCAV **1500** to obtain information as to its location. UCAV **1500** can obtain information as to the locations of other objects, such as other UCAVs, autonomous vessel **100**, and one or more targets, for example, via communication subsystem **1501**. Processing subsystem **1503** can process the locations, as well as directions and speeds of motions, to map out the space within which UCAV **1500** operates. UCAV **1500** can pass its location information and its mapping of space to other objects, such as other UCAVs and autonomous vessel **100**, which can map out the spaces within which they operate.

Dynamics subsystem **1507** provides compensation for dynamics effects on UCAV **1500**. As an example, dynamics subsystem **1507** can adjust elements of UCAV **1500** to compensate for the effect of wind on the flight of UCAV **1500**. As other examples, dynamics subsystem **1507** can adjust elements of UCAV **1500** to compensate for effects of temperature, humidity, barometric pressure, precipitation, and other phenomena on the flight of UCAV **1500**. As another example, dynamics subsystem **1507** can adjust elements of UCAV **1500** to compensate for effects of speed on aerodynamic surfaces of UCAV **1500** and for effects of weight distribution in UCAV **1500**.

Sensor subsystem **1508** can includes sensors for detecting information from the environment around UCAV **1500**. For example, sensor subsystem **1508** can include still cameras, video cameras, infrared cameras, ultraviolet cameras, multispectral cameras, radars, RF sensors, optical sensors, acoustic sensors, pressure sensors, altimeters, airspeed sensors, wind sensors, chemical sensors, and other sensors. Information from such sensors can be used by processing subsystem **1503** and can supplement information used by other UCAVs and autonomous vessel **100**, which can be communicated by communications subsystem **1501**. Information from such sensors can be supplemented by information from sensors of other objects, such as other UCAVs and autonomous vessel **100**, which can be received by communications subsystem **1501**.

Propulsion subsystem **1509** can include motors, for example, for vertical propulsion to keep UCAV **1500** aloft and, for example, for horizontal propulsion to move UCAV **1500** from one location to another. Propulsion subsystem **1509** can include feedback sensors or can obtain feedback from other subsystems, such as navigation subsystem **1506**, to determine actual propulsion provided by propulsion subsystem **1509**.

Power subsystem **1510** can include a battery system, such as a rechargeable battery system, a charging system, a battery management system, and a load management system to manage the operation of UCAV **1500** in response to the state of charge of its battery system. As an example, UCAV **1500** can be configured to return to autonomous vessel **100** as a state of charge of the battery system declines past a predetermined value. The return of UCAV **1500** to autonomous vessel **100** can be coordinated with other UCAVs to avoid collision of multiple returning UCAVs to autonomous vessel **100**. Upon return of UCAV **1500** to autonomous vessel **100**, autonomous vessel **100** can use its power subsystem to recharge the battery system of power subsystem **1510** of UCAV **1500**. With sufficient state of charge in the battery system of power subsystem **1510** of UCAV **1500**, UCAV **1500** can again take flight from autonomous vessel **100** to resume its mission or to be tasked to perform a new mission.

In accordance with at least one embodiment, the autonomous vessel can act as a docking station for a plurality of UCAVs. The UCAVs can be deployed individually or in small numbers, for example, to act as aerial scouts for reconnaissance of potential threats. As the individual or few UCAVs return to the autonomous vessel for replenishment, such as recharging of their batteries, another UCAV or other UCAVs can be deployed from the autonomous vessel to maintain constant vigilance. As one example, the autonomous vessel can manage deconfliction of incoming and outgoing UCAVs. As another example, the UCAVs can coordinate with each other to manage their own deconfliction.

As another example, the UCAVs can be deployed in large numbers, up to and including all of the UCAVs carried by the autonomous vessel. A portion of a large number of UCAVs can return to the autonomous vessel for replenishment, such as recharging of their batteries and, for embodiments where the ordnance is separable from the UCAVs, reloading ordnance.

In accordance with at least one embodiment, the UCAVs can use their own sensing and tracking subsystems to sense and track one or more targets. The UCAVs can coordinate their sensing and tracking of targets using their communication subsystems. The UCAVs can coordinate their employment of ordnance to engage one or more targets using their communication subsystems. In accordance with at least one embodiment, the UCAVs can obtain sensing and tracking information from another source, such as from the surface vessel, from a naval surface ship, from a naval submarine, from an aircraft, or from a spacecraft, such as a satellite.

In accordance with at least one embodiment, the UCAVs can maintain a deployed configuration flying in formation with each other, ready for any threat that may be encountered. In accordance with at least one embodiment, the UCAVs can respond reactively to detection of a threat, forming a flying formation in response to the detection. In either case, the formation may be predefined or may be adaptive to the detected threat. As an example, the formation may be configured to exhibit a swarm behavior dynamically presenting a distribution of UCAVs in airspace configured to optimize a likelihood of interception of the detected threat. As another example, the formation may be configured to exhibit a counter-swarm behavior dynamically presenting a distribution of UCAVs in airspace configured to optimize a likelihood of interception of a large number of simultaneous threats, such as threats flying in the form of a swarm.

As an example, a UCAV can obtain information about an expected flight path of a threat using its own sensor subsystem and tracking subsystem or with the assistance of other assets, such as one or more other UCAVs and one or more naval surface vessels, naval subsurface vessels, aircraft, or spacecraft. The UCAV can extrapolate the expected flight path of the threat to an expected intercept point accessible to the ordnance of one or more UCAVs within the time constraints imposed by the approaching threat. The UCAV can direct itself, another UCAV, or a combination thereof to the expected intercept point. As the threat approaches the expected intercept point, the UCAV or other UCAV or UCAVs directed to the expected intercept can relocate to adapt their position to a refined expected intercept point. In the case of multiple UCAVs being deployed to intercept the target, the UCAVs can be deployed in a formation, such as a uniform spatial distribution or a weighted spatial distribution, in the vicinity of the expected intercept point. In the case of multiple targets against which multiple UCAVs are deployed, the UCAVs can be directed to multiple respective expected intercept points to provide a counter-swarm configuration of the multiple UCAVs to engage the multiple targets. In accordance with at least one embodiment, the expected intercept point or multiple respective intercept points can be based on one or more expected paths of one or more targets, wherein the one or more expected paths can be one or more expected flight paths for one or more airborne threats or one or more expected surface paths for one or more surface threats, such as hostile surface vessels, for example, hydrofoil surface vessels or high-speed gunboats.

The concepts of the present disclosure have been described above with reference to specific embodiments. However, one of ordinary skill in the art will appreciate that various modifications and changes can be made without departing from the scope of the present disclosure as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of the present disclosure.

Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

What is claimed is:

1. An autonomous vessel comprising:

a hull, the hull containing a plurality of subsystems, the subsystems comprising:

a sensor subsystem configured to sense potential target information regarding a potential target;

a database subsystem configured to store target characterization information;

a processing subsystem coupled to the sensing subsystem and to the database subsystem, the processing subsystem configured to process the potential target information according to the target characterization information to confirm the potential target as being a confirmed target; and

an ordnance subsystem, the ordnance subsystem comprising an ordnance magazine configured to store ordnance, the ordnance deliverable by an unmanned combat aerial vehicle (UCAV), the ordnance deployable against the confirmed target.

2. The autonomous vessel of claim **1**, wherein the processing subsystem is configured to provide autonomous control of the autonomous vessel.

3. The autonomous vessel of claim **1**, further comprising:

a communications subsystem configured to provide communication with a second vessel for coordinating engagement of the confirmed target.

4. The autonomous vessel of claim **1**, wherein the UCAV is configured to communicate with a second UCAV deployable from the autonomous vessel for coordinating engagement of the confirmed target.

5. The autonomous vessel of claim **4**, wherein the second UCAV comprises a second communications subsystem configured to communicate with the UCAV, wherein the second UCAV further comprises a second processing subsystem to plan cooperative engagement of the confirmed target by the second UCAV in coordination with the UCAV.

6. The autonomous vessel of claim **4**, wherein the UCAV and the second UCAV are configured to deploy cooperatively with additional UCAVs to form an aerial minefield against the confirmed target.

7. The autonomous vessel of claim **1**, wherein the confirmed target includes a cruise missile, anti-submarine-warfare (ASW) ordnance, or an ASW ordnance delivery system.

8. A system comprising:

an autonomous vessel comprising:

a sensor subsystem configured to sense potential target information regarding a potential target;

a database subsystem configured to store target characterization information;

a processing subsystem coupled to the sensing subsystem and to the database subsystem, the processing subsystem configured to process the potential target information according to the target characterization information to confirm the potential target as being a confirmed target; and

an ordnance subsystem, the ordnance subsystem comprising an ordnance magazine configured to store ordnance, the ordnance deliverable by a plurality of unmanned combat aerial vehicles (UCAVs), at least a portion of the ordnance expendable against the confirmed target.

9. The system of claim **8**, wherein each of the plurality of UCAVs is configured to operate autonomously and cooperatively.

10. The system of claim **8**, wherein each of the plurality of UCAVs further comprises:

a communications subsystem configured to provide communication with others of the plurality of UCAVs for coordinating engagement of the confirmed target.

11. The system of claim **10**, wherein each of the plurality of UCAVs further comprises:

a navigation subsystem configured to identify a respective location of a respective one of the UCAVs relative to the others of the plurality of UCAVs.

12. The system of claim **10**, wherein the plurality of UCAVs are configured to share the potential target information regarding the potential target among each other.

13. The system of claim **8**, wherein each of the plurality of UCAVs further comprises:

a tracking subsystem configured to track the confirmed target.

14. The system of claim **8**, wherein the plurality of UCAVs are configured to deploy cooperatively to form an aerial minefield against the confirmed target.

15. A method comprising:

deploying to a location via a navigation subsystem, a sensor subsystem, and a propulsion subsystem;

maintaining the location via the navigation subsystem, the sensor subsystem, and a dynamics subsystem;

maintaining readiness via a power subsystem, a processing subsystem, a database subsystem, and an ordnance subsystem;

coordinating operation via a communications subsystem, the processing subsystem, the database subsystem, the sensor subsystem, and a tracking subsystem;

confirming a target via the sensor subsystem, the tracking subsystem, the processing subsystem, the database subsystem, and the communications subsystem;

deploying a plurality of unmanned combat aerial vehicles (UCAVs) via the ordnance subsystem, the tracking subsystem, the processing subsystem, and the database subsystem; and

guiding at least one of the UCAVs to the target via the tracking subsystem, the communications subsystem, and the processing subsystem.

16. The method of claim **15**, further comprising:

receiving a tasking order via the communications subsystem.

17. The method of claim **15**, wherein the deploying the plurality of UCAVs comprises forming an aerial minefield of the plurality of UCAVs.

18. The method of claim **15**, wherein the plurality of UCAVs cooperatively develop an engagement plan for at least one of the plurality of UCAVs to expend ordnance against the target.

19. The method of claim **15**, wherein the maintaining the location comprises maintaining a standoff distance around a plurality of naval surface vessels.

20. The method of claim **15**, wherein the guiding the at least one of the UCAVs to the target comprises guiding several of the plurality of UCAVs to a plurality of targets to provide a counter-swarm defense.

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